THE GLASS INDUSTRY

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THE TICKNOR COLUMNAR CHECKER

Manufacture and distribution of new, patented, silica checker is begun on a commercial scale by North American Refractories Co. This is the first published description of the Ticknor design and the results from over two years of operation under severe conditions.

News of uncommon importance to users of regenerative furnaces, especially glass manufacturers, is the announcement of The North American Refractories Co., Cleveland, that it is now producing the new Ticknor columnar checker blocks on a commercial scale. THE GLASS INDUSTRY is privileged to give its readers in the following pages a complete description of the design and properties of the new block, together with detailed information regarding its installation, and actual operation data from several glass-tank applications. To most glass men the Ticknor block will appear unique in material, as well as design; its manner of application will seem to violate certain time-honored principles of checker chamber construction; but the results obtained through the use of this unusual combination of design and material will certainly intrigue interest and warrant careful study.

The Ticknor columnar checker is built up with two special shapes of silica block and arranged to form a series of vertical columns throughout the checker chamber. The use of silica as a material for checkers is not particularly new, since it has been used for this purpose at various times and places in the past; but results have been generally unsatisfactory in glass tanks or, at least, not satisfactory enough to warrant widespread utilization. As will be explained later, silica does have the advantage that it forms a non-clogging residue with the flux, especially at high temperatures, and it was for this reason that it was first tried out in boro-silicate glass tanks at Corning Glass Works.

The first application of straight silica brick checkers was made by Corning several years ago, the brick having the standard size of 9 x 4½ x 2½ in. The purpose of this application and subsequent applications of the same type was to obviate the usual deposition of high-viscosity glass on clay checker brick at high temperatures, which deposition had always caused early clogging and a high cost for checker chamber repairs. In

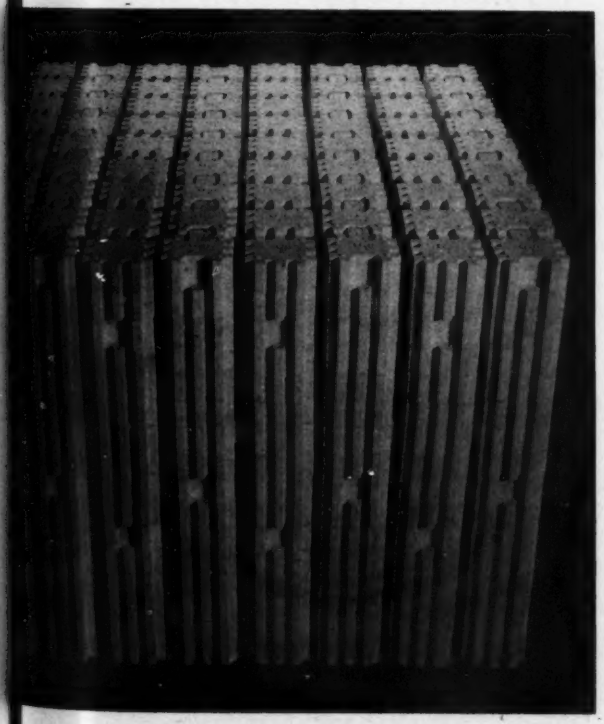


Fig. 1. Ticknor columnar checker setting showing gas flue proportions and relative positions of the spacer brick, as described in this article.

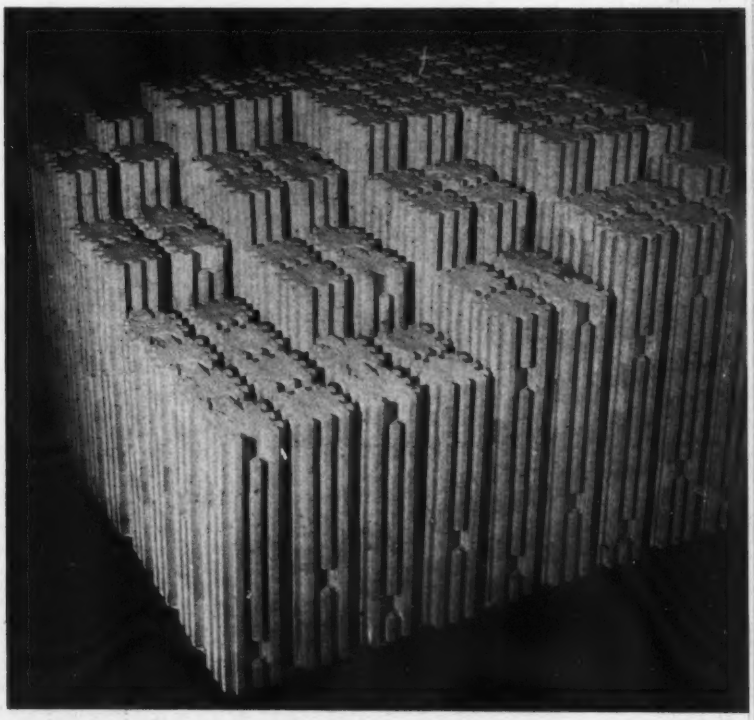


Fig. 2. Setting partially dismantled to show the relative positions of the No. 1 and No. 2 shapes and spacer brick in the eight-course unit.

these silica brick checkers the action of the flux on the brick did actually produce a low-viscosity glass that ran down into the flue and decreased the clogging materially. It followed naturally that, since the use of silica was effective in reducing the clogging tendency of the flux carry-over, the use of large flues in the checker work to lessen the effect of this same clogging might not be necessary.

Ticknor Block Design

The Ticknor columnar checker was the result of further study and experimentation to determine the most efficient combination of size and shape of block, size and shape of air space, and amount of effective block surface exposed to the gases passing through the checker. Two standard shapes of block have been evolved* and the entire checker work is a combination of these two shapes, with suitable spacers which act as braces between the columns. The No. 1 shape, shown in Fig. 3, might be called the standard block, since the No. 2 shape, Fig. 4, is exactly similar except for the recesses to accommodate the ends of the spacers.

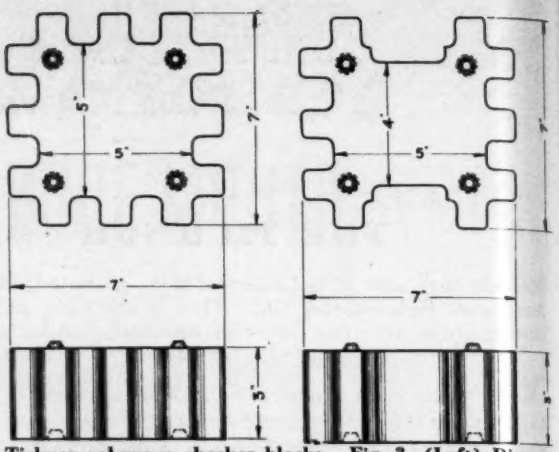
From the dimension sketches it will be seen that the Ticknor block is a rectangular body of silica, 5 in. square by 3 in. high, having three vertical lugs or fins projecting a distance of one inch from each vertical face. The top of each block has four conical protuberances and the bottom has matching indentations, these serving as dowels and holes to prevent the blocks slipping over each other and to maintain alignment of the blocks in the columns. The purpose of the vertical projecting fins is to increase the exposed surface area of the block, these fins being effective because the column of air or gas passes along the vertical grooves of the column without hindrance.

Ticknor Checker Construction

The method of building up a Ticknor checker with No. 1 and No. 2 shapes and spacers is shown in Fig. 1. The first thing of interest is the unusual size and shape of the gas passages, as compared with the more common types of construction. At first glance the practical glass man might be inclined to think that these narrow passages would greatly increase the tendency to clog. Therefore, it seems almost paradoxical that this type of construction has about the same proportion of free passage area as others, that less draft is needed with this structure, that it operates throughout the life of the tank blocks without repair or replacement, and that the silica-flux reaction eliminates practically all clogging trouble.

It might be said that the usual type of checker surrounds a large flue with brick, but the Ticknor construction places the brick in the center and surrounds it with comparatively thin layers of gases. Details of the manner in which the shapes and spacers are assembled to secure a well-bonded, stable checker work may be noted in Fig. 2. This assembly is very ingenious and deserves careful attention, because it is a vital factor in the stability of the built-up structure. All of the necessary changes in block position are encompassed in eight courses of blocks, so the entire structure consists of eight-course units which are repeated as many times as necessary to give the required height, any fraction of a

*U. S. Design patent No. 2,103,602 issued December 28, 1937 to Winton A. Ticknor.



Ticknor columnar checker blocks. Fig. 3. (Left) Dimension sketch of No. 1 shape. Fig. 4. (Right) Dimension sketch of No. 2 shape.

unit being used at the top if necessary. In the eight-course unit, the first, third, fifth and seventh courses consist of No. 1 shapes only. The other courses incorporate both No. 1 and No. 2 shapes in alternate rows, the No. 2 shapes being so positioned that each side of each column is braced clear across the checker chamber once in every eight courses, or at every two feet of height. The positions occupied by the No. 2 shapes and the spacers can be seen in the illustration and it will be noted that the spacers are slightly thinner than the blocks to prevent tilting.

Fig. 5. Upper portion of Ticknor checker for No. 1 port in a borosilicate high temperature tank after a 25-month run. It can be seen that the tops of the columns show least deterioration, although subjected to the highest temperature.

A comparison between the properties of settings composed of Ticknor columnar checkers and those composed of various arrangements of straight title checkers is given in Table I. In this table the heating surface figures give full credit to the horizontal surfaces of the straight tile checkers, although it is well-known that horizontal surfaces are not as efficient as vertical surfaces. The comparison is, therefore, somewhat disadvantageous to the columnar construction. The preferred spacing of the Ticknor blocks is shown in the first column of the table. It might also be mentioned that the straight brick arrangement shown in the last column is the one adopted at Corning after it was found that the silica checker could be operated with less area of gas passage, because of its non-clogging properties.

Ticknor Setting vs. Straight Silica Brick

This geometrical analysis of the preferred Ticknor setting, as compared with the straight tile settings, shows that its equivalent volume of brick per cu. ft. of checker work is from 1.05 to 2.15 times the equivalent volume of the straight settings, thus giving a greater heat-absorbing capacity. Likewise, the heating surface area per cu. ft. of checker work is from 1.43 to 2.13 times that of the straight settings, which means a faster absorption of heat and which might be larger if the horizontal surfaces of the straight tile were included at their real efficiency. But the rather surprising figure is the number of square feet of free area per sq. ft. of horizontal checker area. This compares favorably with the figures for the straight settings, although there is a distance of only three inches between the bodies of the columns and only one inch between the faces of the fins. There is no available proof that the heat transmission between the blocks and the thin streams of gas is more efficient than in the wider flues of the brick construction, but it stands to reason that it might very well be. A setting with these properties can be operated throughout the life of the tank blocks without loss of time or money for repairs and without the deposition of any clogging material that cannot be easily and quickly removed.

Under the action of heat and flux the performance of the Ticknor columnar checker is exceedingly interesting. As previously noted, a glass with a low melting point and a low viscosity forms on the surface of the blocks and runs down the columns into the flue where it can be easily removed. Under certain conditions the temperature at the bottom of the checker may be such that the glass solidifies on the lower blocks of the columns, but this deposition of glass can be melted off by means of a small gas burner introduced beneath the rider arch, whereupon it also runs down into the flue and can be removed. This chain of events is usual in the case of a high-temperature tank and, at the regular melting rate of such a tank, it may be necessary to melt out the glass at the bottom of the checker chamber about once every two months after operation for 10 to 12 months without cleanings. The glass formation and block erosion is most pronounced in the first checkers near the filling end of the tank, the action becoming less and less apparent toward the refining end, of course, where less flux enters the checkers.

Fig. 6. Lower portion of the same Ticknor checker shown in Fig. 5. In this picture the glassy appearance of the columns is evident, as well as the pronounced erosion near the bottom of the checker chamber.

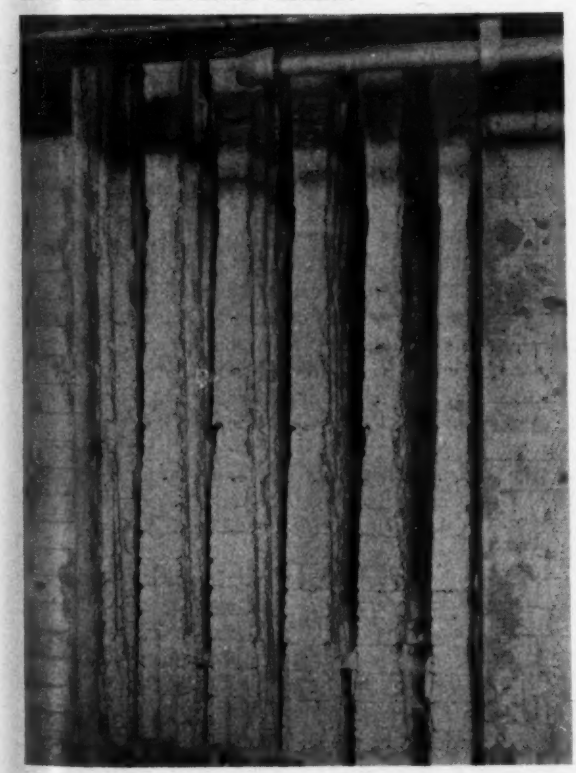


Fig. 7. View showing the appearance of the Ticknor checker in another tank after 15 months operation. Here again the small deterioration at the top and the pronounced erosion near the bottom is evident.

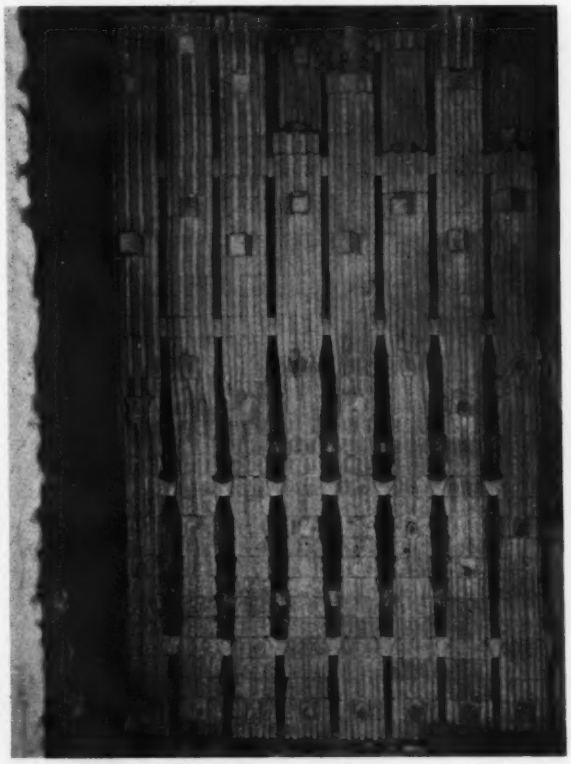


TABLE I.—COMPARISON BETWEEN PROPERTIES OF SETTINGS OF TICKNOR COLUMNAR CHECKERS AND THOSE OF STRAIGHT TILE CHECKERS

	Ticknor Columnar Checkers		Straight Tile Checkers			
	No. 1 & No. 2 8-in. ctrs.	No. 1 & No. 2 9"x8" ctrs.	9x4½x2½ on edge 9"x9" ctrs.	9x4½x3 on edge 9"x9" ctrs.	18x6x3 and 12x6x3 set basket weave	9x4½x2½ on edge 5½"x6" ctrs.
Size of vertical flue	3*	4 & 3*	6½ x 6½	6 x 6	4½ x 7½	3 x 3½
No. pieces per sq. ft. of checker work	6.75 No. 1 2.25 No. 2 2.25 Spacer	6 No. 1 2 No. 2 2 Spacer	4.74	4.74	1.828 (18 x 6 x 3) 1.828 (12 x 6 x 3)	7.43
9-in. equivalent in each piece (101.25 cu. in. basis)	1.10 No. 1 0.98 No. 2 0.24 Spacer	1.10 No. 1 0.98 No. 2 0.30 Spacer	1.00	1.20	3.20 (18 x 6 x 3) 2.13 (12 x 6 x 3)	1.00
9-in. equivalent per cu. ft. checker work	10.17	9.10	4.74	5.69	9.74	7.43
Sq. ft. heating surface per cu. ft. checker work	7.76	6.85	3.74	3.85	3.65	5.49
Sq. ft. free area per sq. ft. horizontal checker area	.40**	.46**	.52	.44	.43	.32

* Distance between main body of Ticknor blocks and not between faces of fins.

** On Ticknor checkers this value includes spacer brick averaged over a multiple of eight vertical courses of checker work.

Heating surface values based on all exposed areas of brick.

TABLE II.—DAILY CONSUMPTION OF NATURAL GAS IN A TANK AT CORNING GLASS WORKS WITH STRAIGHT SILICA-BRICK CHECKERS AND WITH TICKNOR COLUMNAR CHECKERS.

9-in. Straight Silica-Brick Checkers		Ticknor Columnar Checkers	
Days in operation	Fuel consumption in cu. ft. per day	Days in operation	Fuel consumption in cu. ft. per day
28	587,057	23	542,960
56	593,562	51	540,964
91	593,033	79	528,724
119	592,316	107	530,785
147	594,694	135	529,357
		163	546,030
182	600,297	182	540,341
210	623,147	210	581,335
238	667,697	238	587,882
273	731,931	266	618,789
301	590,554	294	627,390
329	702,000	320	615,683
364	639,164	348	624,535
392	604,273	376	618,964
420	583,212	404	604,464
455	598,289	432	613,250
476	684,137	460	631,750
499	707,932	488	647,535
534	627,757		
562	636,081		
590	644,207		
625	608,451		

After a time the fluxing action penetrates further and further into the body of the block until the exposed surface is entirely glassy and after a long run, the glass-forming reaction will have reached nearly to the center of the forming block. When such a stage is reached the checker columns are, to all intents and purposes, made of glass with silica particles at the center. They all look glassy and many of them are glassy right to the core. Since the heat-absorbing properties of glass checkers provide a problem that has not received much study, there is little available data of a practical nature; but at first glance it would seem that the efficiency of the checker might be impaired by the changing of the blocks into the glassy state. All operation data secured during the past few years on several tanks, however, show no improvement of checker action from this cause throughout the longest runs. At any rate the effect cannot yet be segregated, because the loss of checker volume through erosion is also a factor in the deterioration of the checker work.

Effects of Heat and Flux

The deterioration of the checker columns during a long period of operation is well illustrated in Figs. 5 and 6, which show the appearance of the filling-end checkers in a Corning tank after a 25-month run, at which time the tank was shut down for reblocking. Fig. 5 shows the upper portion of the checker work, the lower portion being illustrated in Fig. 6. The glassy appearance of the columns can be readily seen, but the most striking feature is the location of the eroded portions of the columns. A more pronounced erosion near the bottom of the columns where the greatest amount of glassy material is flowing over them would naturally be expected; but it is most surprising that the upper third of the columns shows practically no erosion or other deterioration, although this is certainly the hottest part of the checker work in a high-temperature tank melting borosilicate glass. The tank was fired with natural gas and the flux was, of course, borax.

The checker erosion in another tank, also fired with natural gas, is shown in Fig. 7. This photograph was made after a run of 15 months, when the operation was suspended for a hot repair on the tank. Here again the pronounced erosion near the bottom of the checker work is apparent, together with the very slight deterioration of the columns near the top. After the hot repair this tank was again placed in operation with the original Ticknor checkers, as shown, and is still running.

Fluxing Reaction Under Varying Conditions

With the exception of the one shown in Figs. 5 and 6, no other tanks completely equipped with Ticknor checkers have finished their runs. Examination of the checkers in other tanks making other types of glasses, however, seems to indicate that the absence of deterioration near the top is characteristic of either the borax or the high temperature, or both. Tanks melting soda-lime glasses at lower temperature and at a high rate show erosion commencing almost at the top of the checker columns. Another tank which melts a special soda-lime illuminating glass at a low rate shows no erosion whatever and, in fact, no formation of glass on the surface of the columns. In this tank the surfaces of the columns become covered with a dry, crumbly deposit. This tank has been in operation since the first of the year and it has become standard practice to blow the deposit off the columns periodically with an air blast, in much the same way as soot is cleaned off from boiler tubes.

These widely different reactions of the Ticknor checker under varying conditions of flux and temperature are hard to explain. It is to be expected that the glass-forming tendency will vary with the kind of flux. But the reactions in different temperature zones indicate that there may be a critical temperature at which the absorbing quality of the block changes or where there is a change in the ability of the high-temperature flux fumes to deposit chemically active factors. These matters must remain a matter of supposition until more data on operation have been secured.

On the other hand, the economic advantages of the Ticknor checker seem to be well established by all operation results. The first tank to be completely equipped with the new blocks made a continuous run throughout the life of the tank blocks. This run continued for 25 months, as previously stated, and no maintenance or repair on the checkers was necessary, except for a periodic melting of the glassy deposit at the bottom of the

checker chamber. Previously fitted with silica brick, the checker had never run more than 10½ months without a major repair. At the end of the 25-month run the original Ticknor checkers appeared as in Figs. 5 and 6 and about one-third of the blocks were salvaged for use in the new checkers when the tank was rebuilt, most of the salvaged material coming from checkers farther from the filling end. The operation of the tank during this long run showed a large reduction in draft required and a lower fuel consumption, but the design of the checker chambers and flues had been changed at the time the Ticknor blocks were installed and there was, therefore, no strict basis of comparison between the operation of the Ticknor checker and the straight silica brick formerly used.

Comparison of Operating Results

Operation data from another covering tank is available, however, and the operating history of this tank permits a strict comparison between the results obtained with the Ticknor checker and the straight silica brick. In December, 1936, this tank completed a run of 21 months, the tank having been rebuilt from the bottom prior to the run and the checker chambers filled with 9-in. silica brick. The properties of this setting were as shown in the last column of Table I, and a major repair of the checkers was made at the end of 10½ months.

At the end of the run new tank blocks and Ticknor columnar checkers were installed, no other changes being made. Operation of the tank was resumed February 4, 1937, and still continues, so the operating data secured from this furnace during the interim provides a strict comparison between the Ticknor block and the straight silica brick. The filling rate was practically the same during both runs and, as far as fuel consumption is concerned, the comparison is probably less favorable to the new block, because the crown and upper walls were not renewed and there is now probably a greater heat loss through the thinner crown and walls than there was during the previous run.

Data are now available for a period of 488 days in the present run. As far as the physical results on the checkers is concerned, the run is a repetition of the 25-month run on the other tank. The glass has been melted out of the checker chamber periodically and erosion of the columns seems to be proceeding the same as before, both in amount and in locality. A considerable decrease in draft requirements is apparent. At the beginning of the run with the 9-in. brick checkers the draft used was 0.40 in. of water and this had risen to 0.60 in. at the end of the run. After the installation of the Ticknor checkers the draft requirement was 0.35 in. of water and this has since risen to 0.50 in.

Fuel Saving

The fuel consumption figures showing cu. ft. of natural gas per day, averaged over successive periods during each run, are given in Table II. These results are also plotted in the curves of Fig. 8. Inspection of these curves indicates a greater uniformity of operation with the Ticknor checker, as well as a consistent saving in fuel. When the average fuel consumption rate for 476 days of the former run is compared with that for 488 days of operation with the Ticknor checker, the Ticknor block must be credited with an average fuel saving of 6.05 per cent. Furthermore, the filling rate in the tank during the present run has actually averaged about 3.22 per cent higher than with the straight brick.

The wide fluctuations in the fuel consumption curve for the brick checker installation are difficult to explain.

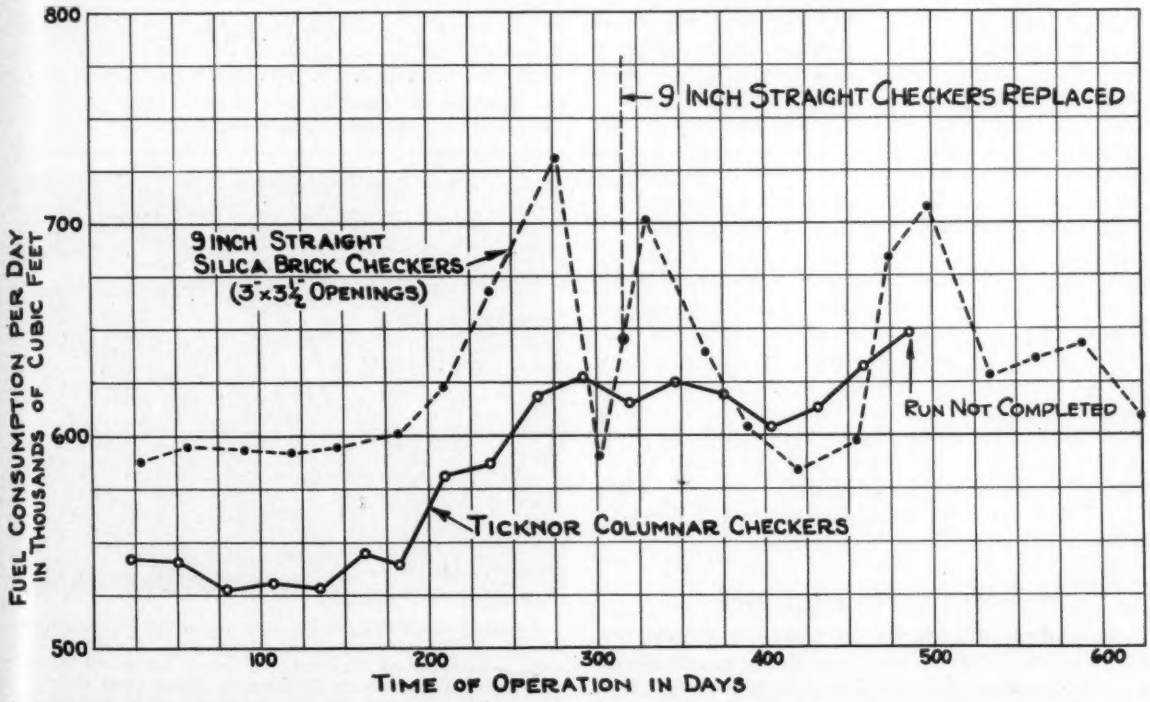


Fig. 8. Chart showing daily consumption of natural gas in a borosilicate tank at Corning Glass Works with straight silica brick checkers and with Ticknor columnar checkers.

As stated, the checker brick had deteriorated to such an extent that a major repair on the checkers was required at the end of 10½ months of operation, this point being near the middle of the upper curve in Fig. 8. It is possible that the calculated fuel rates near this point may have been affected by time lost for repair work, but the available information offers no proof on this point. There is certainly some question as to whether the extremes in fuel consumption can be charged to the straight checker brick, but it is quite evident that the operation of the tank after the Ticknor checkers had been installed was much more uniform than before.

The Ticknor columnar checker has been adopted as standard checker construction for all Corning Glass Works tanks and these tanks are now melting soda-lime bulb and lead tubing glasses, as well as heat resisting glasses. The Pittsburgh-Corning tank at Port Allegany is also fitted with Ticknor checkers and is melting a special soda-lime illuminating glass for glass block. All of these tanks are fired with natural gas. At its Rhode Island division Corning is now installing Ticknor checkers in a rebuilt tank which will be fired with oil. Preparations are also being made by General Electric for the installation of Ticknor blocks in a borosilicate glass tank at Niles. Altogether there are at present a total of nine tanks in operation with Ticknor checkers, with two more under construction.

Economic Advantages with Ticknor Checker

Summarizing the operation data from Ticknor-equipped tanks, it is apparent that an outstanding feature of the new construction is its exceptionally long life without replacement or repair under severe conditions of temperature and flux. Under all conditions the material deposited on the columns has been cleaned out conveniently and easily, thus preventing clogging almost completely. Furthermore, it seems to be well established that less draft is required in furnaces with Ticknor checkers, as compared with straight brick construction. And, finally, for the one installation in which a strict comparison with other types of construction has been possible, a fuel saving of between 5 and 10 per cent, on the basis of fuel per ton of glass melted, is indicated.

To many a practical tank operator the possibility of an actual saving in fuel through any change in checker construction will seem remote, but in this consideration other operation factors, not easily reducible to concrete figures, should be included. The uniformity of the fuel consumption rate has already been demonstrated and this uniformity of operating conditions is also found in other phases of heating control. Reports indicate better control for uniformity of heating from all ports, quicker heating up and lower fuel requirements at the start of a run, greatly reduced stack temperatures, etc. All of these point toward higher efficiency and greater economy in the operation of the furnace.

INCORPORATES SUBSIDIARY

R. R. Underwood, president of Knox Glass Associates, Inc., reports that the Knox Glass Bottle Co. of Mississippi has incorporated a subsidiary corporation in Texas, with principal offices in Houston, to handle the sales of their products throughout that state.

PRODUCTION FIGURES FOR THE GLASS INDUSTRY DURING JULY

Window Glass: During July 1938, the production of window glass was 330,223 boxes which represents 20.3 per cent of industry capacity. As compared with this, July 1937 production was 1,320,406 boxes which represented 81.3 per cent of industry capacity.

Plate glass: The total production of polished plate glass by member companies of the Plate Glass Manufacturers of America during July, 1938, was 5,505,768 sq. ft. as compared to 5,956,386 sq. ft. produced by the same companies in the preceding month, June, and 15,344,855 sq. ft. produced in the corresponding month last year, July, 1937.

Glass Containers: Production of glass containers during the month of July, 1938, was 3,505,943 gross, bringing the 1938 total to 24,319,586 gross. Shipments during July were 3,846,702 gross bringing the 1938 total to 24,744,532 gross.

N. Y. CERAMIC ASSOCIATION TO MEET

The annual meeting of the Ceramic Association of New York will be held at Alfred University, Alfred, N. Y., on Friday, Oct. 7. The program will consist primarily of the presentation of the research results of the Ceramic Experiment Station of the New York State College of Ceramics during 1937-38. It will deal chiefly with heavy clay products research, but whitewares, glass, refractories and enamels will be presented.

WALTER J. REES VISITS UNITED STATES

Walter J. Rees, vice-president of the British Ceramic Society and past president of the Refractories Association of Great Britain, arrived in New York on August 19th. He plans to visit the Refractories Division meeting of the American Ceramic Society at the Bedford Springs Hotel, Bedford, Pa., on Sept. 2-3. Mr. Rees then hopes to attend the Glass Division meeting at Old Point Comfort, Va., if his return to England can be postponed.

The testing ranks in the lamp division of the Westinghouse Electric & Manufacturing Co., Bloomfield, N. J. In this room samples of all Westinghouse lamps are tested for life and lumen maintenance by burning them until they are burned out. During the test the racks of lamps are inspected every 30 minutes for burned-out lamps and to remove lamps for maintenance tests.

THE TERNARY AND QUATERNARY SYSTEMS ALKALI OXIDE—CaO-SiO_2-CO_2*: I

By CARL KRÖGER

Institute for Chemical Technology, University of Breslau

Equilibria, reaction speeds, and their relation to the glass melting process.

The reactions which take place in melting glasses from a simple mixture of alkali carbonate, alkaline earth carbonates and sand are determined by two factors: first, by the position of equilibrium of the reaction which takes place between the components which are present and the newly formed components; and second, by the speed at which these reactions take place. Since the reactions set in among the batch constituents while they are in a solid state and while they are turning more and more into the liquid state, the reaction speed will be determined to a great extent by the first appearance of saturated (eutectic) and unsaturated melts. These temperatures were determined by the author from the melting diagrams of the basic systems.

The conditions necessary for the establishment of equilibrium—namely, constant temperature, constant gas phase, and time for completion—are not present in the melting furnace because rapid melting is strived for. Knowledge of the conditions of equilibrium are important, nevertheless, insofar as it gives information concerning the direction in which the reaction will proceed and the limits which bound it, under what conditions it can go to completion and when it must remain incomplete. Equilibria investigations obtain their full value when applied to the melting process only in conjunction with investigations of reaction speeds and reaction dynamics.

1. The System Li_2O-CaO-CO_2

(*a*) *Li_2O-CaO.* The melting diagram of this binary system has not yet been investigated.

(*b*) *Li_2O-CO_2.* As a single, congruent melting compound, there occurs in this system Li_2CO_3. Melting point 732°, density 2.094. For the interval 800° to 1000° C., $d = 1.765\text{-}0.00034\ (t\text{-}900)$. The crystals form six-side prisms and are strongly doubly refractive. Refractive index for sodium light: $\alpha = 1.428$; $\beta = 1.567$; $\gamma = 1.572$.

Li_2CO_3 gives a noticeable CO_2 pressure only above its melting point. The dissociation equilibrium is, therefore, divariant—that is dependent on the quantity of Li_2O dissolved in the melted Li_2CO_3. The initial pressures amount to:

t(°C)	851	963	1034	1055
p(mm)	17	58	119	153

With 10 per cent Li_2O, it is 74 mm. at 1074°; with 18.5 per cent Li_2O, 26 mm.; with 21 per cent Li_2O, only 14 mm.

(*c*) *CaO-CO_2.* The melting diagram from 0 to 50 mol. per cent CO_2 can be realized only at high pressures. The compound $CaCO_3$ (with 0.38 per cent CaO) melts under a CO_2 pressure of 1025 atmospheres at 1339° C. By additions of CaO, this melting point is lowered, and in fact the eutectic lies at 1240° and 50 per cent CaO with a CO_2 pressure of 39.5 atmospheres.

$CaCO_3$ occurs in several polymorphic modifications. The most stable form is calcite, which occurs in only one stable form. Monotropic forms are aragonite and the still more unstable fibrous vaterite, which corresponds to μ-$CaCO_3$. Another modification called "denser limestone" has been reported.

Denser limestone: sp. gr. 2.884.

Vaterite = μ-$CaCO_3$: hexagonal plates or flat star-shaped crystals. Sp. gr. 2.54. Optically positive. Index of refraction $\epsilon = 1.650$, $\omega = 1.550$.

Aragonite: Sp. gr., $d_{24} = 2.930$. Optically biaxial. Index of refraction for sodium light: $\alpha = 1.530$, $\beta = 1.681$, $\gamma = 1.686$. Dissociation temperature 910° C.

Calcite: Sp. gr. $d_{22} = 2.718$. Crystallizes in hexagonal rhombehedra; is optically uniaxial. Index of refraction in sodium light $\omega = 1.658$, $\epsilon = 1.486$.

The dissociation of calcite is not a fully monovariant equilibrium. The pressure with increasing CO_2 liberation is not reproducible. This is caused by the formation of a phase of variable composition besides CaO and unstable $CaCO_3$. The nature of the substance, its grain size, as well as the heating conditions, are of great influence on the quantity and composition of the variable phase and hence of the pressure established. The decomposition temperature of $CaCO_3$ varies between 886° and 915°. For a 0.02 mm. grain it amounts to 905°, for 0.05 mm. 920° and for 0.1 mm. 923°.

For a particle size of 10 to 20 μ, the following table gives the temperature relations of dissociation pressure with a CaO content up to 30 per cent:

t(°C.)	440	569	701	728	759	809	830	850
p(mm)	4	8	31	59	103	239	306	409

The relation of CaO content at 840° is shown in the next table:

CaO(%)	7	15 to 20	35	55 to 80	95
p(mm)	370	340	310	250	200

Datum of a dissociation temperature without a simultaneous datum of the degree of decomposition of the $CaCO_3$ is, therefore, incomplete.

(*d*) *Li_2O-CaO-CO_2.* The binary system Li_2CO_3-$CaCO_3$ is normally eutectic—a double salt does not occur. The eutectic lies at 40 per cent $CaCO_3$ and 662°.

2. The System K_2O-CaO-CO_2

(*a*) *K_2O-CaO.* Melting point investigations in this system have not yet been published.

(*b*) *K_2O-CO_2.* There exists the congruent melting compound K_2CO_3. Melting point 891°. Sp. gr. $d_{18} = 2.428$. For liquid K_2CO_3 above its melting point up to 1050°, $d = 1.900—0.00046\ (t\text{-}900)$. K_2CO_3 does not crystallize well; it forms a jumble of little flakes of very high double index of refraction.

The dissociation pressures of the compound are very small up to the melting point and are strongly dependent

*Abstracted by Robert F. Ferguson from *Glastechnische Berichte* 15, 335-346, 371-379, 403-416 (1937), and published with the kind permission of the author and the publishers.

from the start on small K_2O content. The following are the temperature relationships:

t(°C.)	1000	1100	1200	1300	1350	1400
p(mm)	2	7.4	10.4	15	19.6	35.6

(*c*) *K_2O-CaO-CO_2.* K_2CO_3 with a mixed crystal formation up to 16 mol. per cent $CaCO_3$ can be heated up to 755°. Furthermore, the congruent melting compound $K_2Ca(CO_3)_2$ is formed. The eutectic between this compound and the saturated mixed crystal lies at 755° and 40 mol. per cent $CaCO_3$. The melts show a small CO_2 dissociation which increases with temperature and at higher temperatures leads to CaO separation.

$K_2Ca(CO_3)_2$: melting point 813°, sp. gr. 2.465, index of refraction $\epsilon = 1.48$, $\omega = 1.530$. The compound forms optically negative uniaxial crystals with cleavage.

The dissociation of the double carbonate proceeds as follows: From the beginning up to the melting point of the compound, the observed pressures correspond to the $CaCO_3$ dissociation, then at temperatures above 750° it falls behind more and more. After about 20 per cent CO_2 release, there occurs a reaction in the melt between 900° and 1000°, and the pressures observed between 36 per cent and 53 per cent CO_2 release lie considerably higher than the pure $CaCO_3$ dissociation. The pressures indicate the formation of a new compound $2CaCO_3$-K_2CO_3. There is no noticeable sublimation of the melt.

3. The System Na_2O-CaO-CO_2

(*a*) *Na_2O-CaO.* The melting diagram of this system has not yet been prepared.

(*b*) *Na_2O-CO_2.* The only compound of this system, Na_2CO_3, melts congruently. Melting point 860°. It has an inversion point at 450°. Sp. gr. 2.476 and 2.533. In the molten condition between 868° and 1048° the equation is $d = 1.9445 - 0.00040\ (t\text{-}900)$. The crystals are negatively double refractive $n_{Na} - n_D = 0.293$.

Na_2CO_3 dissociates noticeably only above its melting point. The CO_2 pressures are, therefore, dependent on both temperature and also Na_2O content of the melt. The following temperature relations have been given, although very small amounts of Na_2O reduce the pressure:

t(°C.)	1000	1100	1200	1300	1400
p(mm)	1.5	5.5	14	29	66

No volatilization of soda occurs up to 850°, but above that, the following figures are typical:

Time of heating (hrs.)	Temperature °C.	Loss in weight (%)	% Dissociation
3	1025	5.5	0.37
6	1050	20.9	2.25

(*c*) *Na_2O CaO-CO_2* With from 0 to 28 mol. per cent $CaCO_3$, homogeneous mixed crystals of the habit of pure $CaCO_3$ occur. The maximum melting point of the mixed crystal is found at about 0.2 $CaCO_3$ and at about 889°. The pressure effect is very slight. The eutectic between the high Na_2CO_3 mixed crystals and the double compound $Na_2Ca(CO_3)$ lies at 0.38 $CaCO_3$ and 786°. With higher $CaCO_3$ content, $CaCO_3$ crystallizes out of the melt. At one atmosphere CO_2, this separation at 890° and 0.62 $CaCO_3$ is limited by the $CaCO_3$ decomposition. CaO once separated out is reconverted only with difficulty, since the heavier CaO sinks to the bottom of the melt.

$Na_2Ca(CO_3)_2$. Melting point 813°. The double carbonate forms large, optically negative, uniaxial crystals of decided cleavage towards the base. Sp. gr. 2.540. Index of refraction $\epsilon = 1.504$, $\omega = 1.547$.

The dissociation pressures up to 800° are only a little under that of the $CaCO_3$ dissociation. Up to 15 per cent CO_2 release, they fall off only a little, but with higher CO_2 release they fall off rapidly and go over to the pressure of pure Na_2CO_3 when half of the double carbonate is destroyed.

4. The System Na_2O-K_2O-CaO-CO_2

(*a*) *Na_2O-K_2O-CO_2.* The portion K_2CO_3-Na_2CO_3 in this system behaves binarily. The two carbonates form a series of mixed crystals without gaps with a melting minimum at 712° and 0.46 K_2CO_3. The CO_2 loss from this melt under a CO_2 pressure of one atmosphere is very small.

(*b*) *Na_2O-K_2O-CaO-CO_2.* The binary portion $K_2Ca(CO_3)_2$-$Na_2Ca(CO_3)_2$. Both alkali double carbonates form a continuous series of mixed crystals. The melting points differ only a little from each other. On the liquidus curve there occurs a minimum at 805° and 0.26 $Na_2Ca(CO_3)_2$.

The ternary region Na_2CO_3-K_2CO_3-$Na_2(K_2)Ca(CO_3)_2$. [The melting behavior of the mixture according to Niggli is shown in Fig. 1. MN shows the curve of the four phase equilibrium: mixed crystal $Na_2(K_2Ca)CO_3$ + double carbonate mixed crystal $\rightleftarrows$ melt + CO_2.] The minimum of this curve lies at 693°. At higher $CaCO_3$ content, the melt gives off CO_2, since its dissociation pressure is greater than one atmosphere. [The $Na_2(K_2Ca)CO_3$ mixed crystal curve is given in de. In the triangle above de there is in the solid state a mixture of mixed crystals $Na_2(K_2Ca)CO_3$ with double carbonate mixed crystals $Na_2(K_2)Ca(CO_3)_2$.]

(*c*) *The reaction speed in the alkali-CaO-CO_2 systems.* The rate of decomposition of the alkali carbonate is great. Temperature fluctuations express themselves immediately in fluctuations of the equilibrium pressure. The decomposition of calcium carbonate on the other hand requires, even at high temperatures, minutes; and at lower temperatures to full reversibility, hours. The dissociation speed is dependent in general on the partial pressure of carbon dioxide and this in turn is dependent on the diffusion of the carbon dioxide through the solid carbonate. Hence, follows a logarithmic increase of the dissociation speed with temperature and its dependence on the nature and grain size of the substance. According to Whiting and Turner, the dissociation speed for precipitated $CaCO_3$ is not so great as that for calcite of about the same grain size. Calcite, grain size 0.063 mm., is fully decomposed in 85 hours at 610° under the conditions of the test, and in 2.5 hours at 750°, and in one hour at 800°. The relation of dissociation speed to CO_2 partial pressure can be approximated by the equation $V = K(P\text{-}Po)$, in which Po is the equilibrium pressure and P the prevailing pressure. Deviations are explained by the formation of new "keims" (nuclei).

The cessation of pressure with the double carbonates takes place with greater speed; with high conversion, however, with $K_2Ca(CO_3)_2$ there is a much slower decomposition. The cessation of CO_2 pressure in those cases requires over 50 hours and in some cases up to 500 hours.

The decomposition speed of the carbonates follows the

law for monomolecular reactions, that is, the speed $V = dx/dz$ is directly proportional to still undecomposed quantity a—x at the time Z:

$$\frac{dx}{dz} = K\,(a-x),\quad K = \frac{1}{Z}.\ \ln\frac{a}{a-x}$$

The temperature relations of the velocity constant K follows Arrhenius' equation, that is, it increases logarithmically with temperature:

$$k = c.e^{-aT},\quad \ln k = \frac{a+b}{T}$$

The temperature increment "a" is related to the heat of reaction E according to the equation $a = E/R$, that is, by multiplication of "a" by 4.571 gives E in calories.

The decomposition speed constant K referred to 1 mol. $CaCO_3$ for the temperature 610°, 700°, 750°, and 800° assumes the following values: $K \cdot 10^4 = 6.3$; 81; 485; 1000. On the other hand, Slonim finds:

t(°C.)	750	775	800	830	850
K	0.01705	0.02753	0.04531	0.07923	0.1132

The influence of grain size on the decomposition speed has not been clearly established. Within a short time the decomposition speed dy/dz of $CaCO_3$ is constant. According to Furnas, $dy/dz = k$; $y = kz$ + constant; that is the decomposition product exercises no acceleration or retarding influence.

The decomposition speed of the double carbonate $Na_2CO_3.CaCO_3$ was measured by Howarth, Sykes and Turner. At 800° it was given by the above monomolecular decomposition; at 700°, however, the equation, $Z = f.\,(1 - \sqrt[3]{100-x})/100$, expresses the result better.

(*d*) *Thermochemistry of carbonates.*[1]

(1) Heat of formation.

$[Li_2O] + (CO_2) = [Li_2CO_3] + Q$
$Q_{20} = 54.23$ kcal
$[K_2O] + (CO_2) = [K_2CO_3] + Q$
$Q_{20} = 94.26$ kcal
$[Na_2O] + (CO_2) = [Na_2CO_3] + Q$
$Q_{20} = 75.92$ kcal
$[CaO] + (CO_2) = [CaCO_3]$ (calcite) $+ Q$
$Q_{20} = 42.6$ kcal
$Q_{20} = 42.52$ kcal
Dense limestone $Q_{20} = 42.62$ kcal
$[K_2CO_3] + [CaCO_3] = [K_2Ca(CO_3)_2] + 0.72$ kcal
$[Na_2CO_3] + [Li_2CO_3] = [Na_2Li_2(CO_3)_2] + 1.08$ kcal

(2) Heat of fusion

Na_2CO_3 : 85.8 cal/g

(3) Heat of conversion

Na_2CO_3 : 4 cal/g
$CaCO_3$: Aragonite → calcite 0.03 kcal/mol

(4) Average specific heats for constant pressures.

Na_2CO_3	(18°— 48°)	0.246
K_2CO_3	(23°— 99°)	0.2162
$CaCO_3$	(20°—100°)	0.2087
	(20°—300°)	0.244
	(20°—500°)	0.2512
	(20°—900°)	0.2657
Marble	(18°— 50°)	0.1994
Aragonite	(0°— 20°)	0.1899

[1]The solid phases are set in square brackets, the gaseous phases in parentheses, and nothing is used around the liquid phases.

5. The System Li_2O-SiO_2-CO_2

(*a*) *LiO_2-SiO_2* Fig. 2 gives the melting diagram according to Kracek. Three compounds appear: Li_4SiO_4, $Li_2Si_2O_5$, and Li_4SiO_4. The disilicate melts incongruently at 1033° with formation of Li_4SiO_4 and a melt with 80.1 per cent SiO_2. The $Li_2Si_2O_5$-tridymite eutectic lie at 1028° and 82.2 per cent SiO_2. Li_4SiO_4 decomposes at 1256° into Li_2O and a melt with 50.9 per cent SiO_2. The eutectic between Li_4SiO_4 and Li_2SiO_3 is at 1024° and 55.3 per cent SiO_2. Melts with more than 50·3 per cent Li_2O cannot be investigated because of the volatility of the Li_2O.

On heating in a vacuum, Li_2O evaporates. The decomposition speed of $SiO_2.2.56\ Li_2O$ decreases slowly at 1100° and becomes suddenly small when the composition $SiO_2.2\ Li_2O$ is reached. In every case, the decomposition speed of Li_2SiO_3 is very small at 1300° when the composition $Li_2Si_2O_{11}$ is reached.

Li_4SiO_4. Melts incongruently at 1256°. Sp. gr. $d\,\frac{4}{15} = 2.392$. Forms rounded grains. Double refractive, positive, optically one or two axial. Refractive index for sodium light $\alpha = 1.602$, $\gamma = 1.610$. It is decomposed by boiling water and the weakest acids.

Li_2SiO_3. The congruent melting point is so well marked on the cooling curve that Li_2SiO_3 can be used as a standard substance for thermo-elements. The melting temperature is 1201°. Sp. gr. $d\,\frac{4}{15} = 2.520$. Forms long, six-sided prisms, optically positive, uniaxial, optically negative. Refraction for sodium light $\omega = 1.591$, $\epsilon = 1.611$. Soluble in acids, insoluble in methyl and ethyl acetate.

$Li_2Si_2O_5$. Melts incongruently at 1033°. Sp. gr. $d\,\frac{4}{25} = 2.454$. Forms large plates with positive double refraction. Refractive index $\alpha = 1.547$, $\beta = 1.550$, $\gamma = 1.558$. $Li_2Si_2O_5$ shows a slight mixed crystal formation with LiO_2 and SiO_2. The mixed crystals decompose on cooling to 939° and 960° respectively. The viscosity of

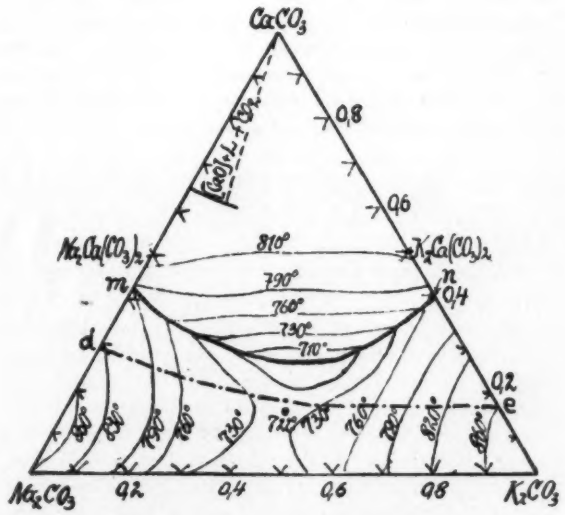


Fig. 1. The Na_2CO_3-$CaCO_3$-K_2CO_3 System (Niggli).

the disilicate melt decreases from 700 poise at 100° to 30 poise at 1400°.

$Li_2Si_2O_5$ is formed on heating the component oxides in a solid state at 1100° but does not crystallize out of the melt. Occurs in fine needles or in thin, flexible crystals which are not attacked by concentrated sulphuric acid.

(*b*) *Li_2O-SiO_2-CO_2.* Lithium disilicate does not react with carbon dioxide below 750 atmospheres either at low temperatures, or in the melt. The first equilibrium, therefore, takes place between di- and meta-silicate.

The Stable Equilibria

1. $[Li_2Si_2O_5] + [Li_2CO_3] \rightleftarrows 2\ [Li_2SiO_3] + (CO_2)$.

The reaction pressure of the action of Li_2CO_3 on $Li_2Si_2O_5$ is at first bivariant. There is formed with an absorption of heat the binary mixed crystal Li_2CO_3. x $Li_2Si_2O_5$, which can take up only a little Li_2SiO_3 into solid solution. Only when a saturation of this mixed crystal is reached having a composition 0.9 mol $Li_2Si_2O_5$, 0.2 Li_2SiO_3 and 0.9 Li_2CO_3 the above monovariant equilibrium is established with the following reproducible pressures:

t (°C)	318	370	445	495	520	540	550
p (mm)	10	50	90	174	309	633	784

With Li_2CO_3 excess in the proportions 1 $Li_2Si_2O_5$: 2 Li_2CO_3, the equilibrium remains bivariant even with rapid Li_2SiO_3 formation, since the saturation of the ternary Li_2CO_3 mixed crystals is no longer obtained. There are the following pressures:

mol. fraction Li_2SiO_3					
0 to 0.1	t	332	389	445
	p	80	227	336
0.1 to 0.33	t	428	524	553
	p	250	741	928
0.33 to 0.47	t	431	498	535
	p	15	115	266

The reaction takes place in the solid state. The establishment of the pressure with increased conversion requires longer and longer time—30 to 200 hours.

With the inverse reaction, the taking-up of CO_2 by Li_2SiO_3, on the other hand, a rapid saturation of the resulting carbonates with Li_2SiO_3 and $Li_2Si_2O_5$ results, so that the absorption ceases at the pressure of the monovariant equilibrium. The end pressure amounts to 722 mm. at 545° after 130 hours, 317 mm. at 515° after 300 to 330 hours. At high temperatures (1250°) no absorption of CO_2 takes place under 750 atmospheres by the homogeneous melted metasilicate.

2. $[Li_2SiO_3] + Li_2CO_3 \rightleftarrows [Li_4SiO_4] + (CO_2)$. The reproducible pressures found for this equilibium are:

t (°C)	545	585	620	677	706	725	739
p (mm)	20	57	103	254	433	851	939

The pressure is established within one or two hours; even so, the speed of the reversible reaction is very great, so that here, too, equilibrium is reached in a short time. Before these pressures of the monovariant equilibrium, in a range up to 5 per cent carbonate, somewhat higher pressures are observed which belong to a bivariant equilibrium. During the conversion, the substance sinters; that is, there is a partial conversion to melt which at first can be saturated only with Li_2SiO_3. Hence, the equilibrium is bivariant. Even with 5 per cent carbonate conversion, saturation with Li_4SiO_4 is

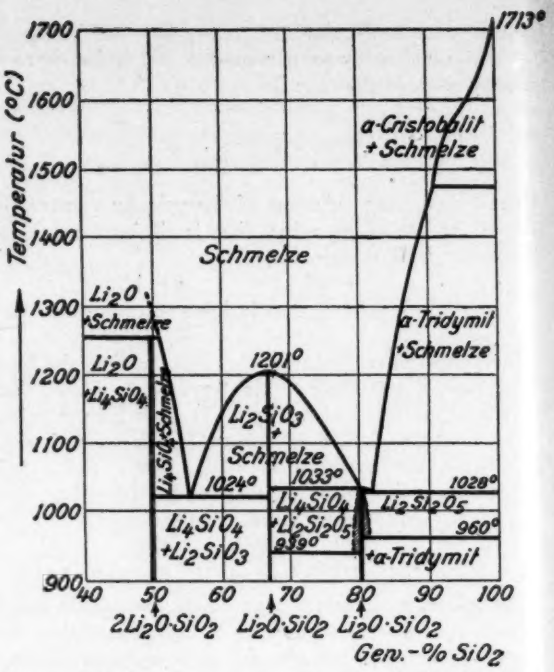


Fig. 2. Melting diagram for LiO_2-SiO_2 System (Kracek).

reached so that in the higher conversion ranges the pressure of the above equilibrium is established.

3. $[Li_4SiO_4] + 2[Li_2CO_3] \rightleftarrows [Li_6Si_2O_7] + 2(CO_2)$. The formation of saturated and unsaturated melts leads to monovariant, bivariant, and trivariant equilibria. The equilibria observed at various temperatures are as follows:

(a) Up to 675°. $[Li_4SiO_4] + [Li_2CO_3] \rightleftarrows [Li_6Si_2O_7] + (CO_2)$. The reproducible pressures in relation to temperature are:

t (°C)	608	640	660	670
p(mm)	9	35	42	50

(b) From 675° to 780°. $[Li_4SiO_4] + [Li_2CO_3] \rightleftarrows [Li_6Si_2O_7] + (CO_2)$. The following pressures were observed:

t (°C)	680	705	735	750	770
p (mm)	85	101	165	222	336

(c) Above 780°. $Li_4SiO_4 + Li_2CO_3 \rightleftarrows [Li_6Si_2O_7] + (CO_2)$. For this bivariant equilibrium the following pressures were obtained for various degrees of conversion:

Up to 17 per cent carbonate converson:

t (°C)	752	784	808	815	830	870
p (mm)	119	224	344	563	750	983

For 17 to 42 per cent carbonate conversion:

t (°C)	850	940
p (mm)	314	733

For 42 to 56 per cent conversion: 960°C, 381 mm.

With molecular proportions 2 carbonate to 1 Li_4SiO_4, the pressure does not decrease so rapidly with increasing conversion. After 50 per cent conversion, the pressures of the following monovariant equilibrium

$Li_6Si_2O_7] + Li_2CO_3 \rightleftarrows [Li_8SiO_6] + (CO_2)$ were:

820°	825°
147 mm	158 mm

The pressures of this equilibrium establish themselves

(*Continued on page* 346)

THE GLASS DIVISION IN RETROSPECT

By A. N. FINN

Last April, at New Orleans, when the Glass Division was celebrating its Twentieth Anniversary, Chairman Finn made very interesting references to the early years of the Division's history. Space limitations prevented their inclusion in the report of that meeting, but the record was carefully preserved against some future and appropriate occasion. This month, at Old Point Comfort, the Division holds its Tenth Summer meeting. Though a decade is admittedly not half as important in the passage of time as a full generation, we venture the opinion that future historians will find the Old Point Comfort meeting not one whit less interesting than New Orleans. So we dust off the manuscript and present it herewith for the enjoyment of our readers.—The Editor.

Organization of the Glass Division was effected in 1919. Previous to that time, the feeling had prevailed for some years that a divisional reorganization of the American Ceramic Society was imperative. Meetings had been of the one program type, and no group encompassing such diversified interests as glass, enamels, white wares, refractories, brick, tile, terra cotta, and abrasives could find a common interest in a joint program. Another factor which may have influenced contemporary thinking was the proposal made about that time to form a Pittsburgh section of the Society of Glass Technology.

At a meeting of the Board of Trustees in 1918, E. T. Montgomery offered a motion that President H. F. Staley appoint "a representative of each division to be organized," and it fell to the lot of C. H. Kerr of the American Optical Company to create a glass division.

To this end, fifty-seven of the assignable members held an organization meeting in Pittsburgh on February 3, 1919. C. H. Kerr presided as organizing chairman, and S. R. Scholes as secretary pro tem. The meeting elected Mr. Kerr as first chairman of the Division, and E. W. Tillotson as the first secretary. A By-Laws Committee was appointed consisting of W. M. Clark, S. R. Scholes, E. W. Washburn, J. C. Hostetter, R. L. Frank, F. A. Kirkpatrick and C. D. Grafton.

Reading over the minutes of that meeting, one can almost see the fifty-seven members, having elected their officers, next asking themselves the question: "Now that we have an organization, what will we do with it?" Professor Silverman discussed the standardization of raw materials. G. E. Barton asked what work the Bureau of Standards had under consideration, and Mr. Williams told about the work on optical glass as well as plans to investigate colored glass, decolorizing new compositions, refractories, tank blocks, etc. Professor Silverman offered to place at the disposal of the Division his bibliography on glass, complete up to 1916 and containing some 10,000 references, and this offer resulted in the appointment of a Committee on Bibliography. J. R. Montgomery called attention to much unpublished work of Government laboratories, universities, etc., and suggested an effort be made to secure these.

The day following its organization, at 2:30 p.m. February 4, the new Glass Division held its first formal session. Thirty-nine were present and secretary Tillotson presided. Only one paper was read: "Gold Ruby Glass," by H. T. Bellamy. A discussion followed of four other papers that had been read at the general session that morning: "Note on the Casting of Porcelain Glass Pots," by J. W. Wright and D. H. Fuller; "Procedures in the Manufacture of Optical Glass," by W. J. Williams and C. C. Rand; "Notes on the Gases Dissolved in Optical Glass," by E. W. Washburn; and "Defects and the Testing of Optical Glass," by A. R. Payne.

The question of gas producers was discussed informally and a Committee on Papers was appointed to confer with the Publications Committee to secure a number of the *Journal* devoted specially to glass.

During the next two or three years prospects for a successful continuation of the Division probably did not look so bright because at the 1922 meeting which was held in St. Louis, Dr. J. C. Hostetter, in speaking as chairman-elect of the Division, said:

"Before coming to St. Louis to this meeting, I was wondering in my mind as to what the future of this Division would be. It seems to me that if we didn't have a successful meeting in St. Louis, the future meetings would be even less successful, and this would mean more or less the end of the Division. As you recall, in Philadelphia, we had a program filled with papers and talks and the time wasn't sufficient to cover the program. The

As they were, Left to right: J. C. Hostetter, Alexander Silverman, Francis C. Flint, J. T. Littleton.

number presented since has steadily declined, and at this meeting, while we had papers listed, in many cases the papers weren't forthcoming for one reason or another, and for certain reasons the men on the program didn't come."

He followed this with a plea for help, support and cooperation to keep the Division alive.

It can be safely said that the organizers of the Division planned better than they knew, for it is doubtful if they could foresee the decided increase in Division membership and interest in our activities, both of which are reflected in the tone of subsequent meetings, the attendance at the meetings, and the whole-hearted support the chairman of the Division receives from his official family, from the "old guard," and from the membership in general.

The total membership of the Society is now approximately 2,700 of which some 300, 11 per cent, are assigned to the Glass Division. The total registration at this meeting is approximately 500 and we have about 60 members attending.

TERNARY AND QUATERNARY SYSTEMS

(*Continued from page* 344)

quickly, but, nevertheless, the reactions are reversible.

Quartz at 900° dissolves in molten Li_2CO_3 with the release of a quantity of CO_2 which is 2 to 4 times the equimolar amount. This means there must be formed a silicate lower in silica than Li_4SiO_4. Since the CO_2 loss with very small quantities of SiO_2 approaches 400 per cent, the silicate can be Li_6SiO_6.

The Stable Equilibria

1. $[SiO_2] + [Li_2CO_3] = [Li_4SiO_4] + (CO_2)$. The action of quartz on Li_2CO_3 always forms metasilicate, regardless of the proportion of the mixture. The pressures established in a long time, 100 to 500 hours, were as follows:

t (°C)	312	437	472	485	508
p (mm)	2	96	290	482	1056

2. $[Li_8SiO_{11}] + 4[Li_2CO_3] = 5[Li_4SiO_4] + 4(CO_2)$. With samples of Li_2O—SiO_2 prepared at 1000° to 1100°, whose molar proportions lay exclusively between 1:3 and 1:5, there were not obtained the high pressures of the SiO_2 reaction on the Li_2CO_3 in contrast to the tests with molecular ratio of 1:7. This proves the presence of a higher polysilicate, $Li_2O.5SiO_2$, which gives the following reproducible pressures with 4 mol Li_2CO_3:

t (°C)	312	450	500	560	570
p (mm)	25	100	172	540	850

The pressure is established in about 50 to 200 hours.

Both these instable equilibria were obtained only because the CO_2 compound was formed extremely slowly by the metasilicate with disilicate formation.

(This informative article by Dr. Kröger will be continued in the October issue of The Glass Industry. *In the second instalment, he will discuss the K_2O-SiO_2-CO_2 system, the Na_2O-SiO_2-CO_2 system and the CaO-SiO_2-CO_2 system.—The Editor.)*

"WINDOW CONDITIONING" SPONSORED BY LIBBEY-OWENS-FORD

Among lumber dealers the Libbey-Owens-Ford Glass Co. is sponsoring a merchandising campaign to exploit the advantages of "window conditioning," that is, the double glazing of windows in homes. Coincident with this effort, the company will also institute a campaign of advertising in national magazines, designed to acquaint home builders and owners with the benefits derived from the use of double glass in windows.

Test figures from many authoritative sources indicate quite striking savings from the use of double-glazed windows. Fuel savings of from 20 to 30 per cent are noted and a comparison with the effects of other accepted methods of house insulation indicates that properly conditioned windows have a greater influence on the fuel cost than any other single method of insulation. It is calculated that, in an average home, "window conditioning" will pay for itself in less than two heating seasons.

Many forms of window construction are available for securing the advantages of double glazing. A usual and effective method is the use of the so-called storm sash which, in modern design and with good glass, are neat in appearance and easy to install, since they can be hung on the same fixtures that hold the screens in summer. For new houses there are various patented forms of double glazed sash.

Another beneficial feature of a conditioned window is the elimination of fogging, frosting and dripping under conditions of proper inside humidity. On account of the dead air space the inside panes of a double-glazed window remain more nearly at room temperature and moisture is deposited only under extreme conditions of low outside temperature and high inside humidity. A feature of the advertising campaign on window conditioning is the inclusion of new ideas in window design for homes.

V. V. KELSEY HEADS DOMINION MINERALS

V. V. Kelsey has resigned his position as vice-president and sales manager of the Consolidated Feldspar Corporation, effective Sept. 1, to become president of Dominion Minerals Incorporated of Washington, D. C.

Dominion Minerals is the owner of extensive mineral properties, located on the Southern Railroad near Lynchburg, Virginia. The company will develop particularly its silicate rock product deposit, containing alumina, lime, soda and potash. Headquarters of the corporation will be located at 719 Fifteenth St., N.W., Washington, District of Columbia.

KNOX SALES REPRESENTATIVES MEET

On July 21, 22 and 23 practically all of the sales representatives of Knox Glass Associates, Inc., east of the Rocky Mountains, met at the country home of R. R. Underwood, president of the company, for their fifth annual sales convention. The sales people were familiarized with administrative and manufacturing problems and in turn gave some useful hints to the home forces. In addition to the serious business, a good share of the time was devoted to fun and sports, even to the extent of organizing a 250-piece brass band.

THE ROLE OF GASES IN GLASS:
II. CARBON DIOXIDE EVOLUTION AND METHODS OF FOLLOWING REACTIONS IN THE BATCH

By W. WEYL and A. G. PINCUS

Department of Ceramics, Pennsylvania State College

In the first article of this series, published in July, we pointed out that it is essential to maintain an oxygen balance in both the melt and the product for control of fining, decolorization, and color. Carbon dioxide differs from oxygen, however, because it is desirable to eliminate it as completely as is practical after its function in the melting process has been completed. If this gas is not driven off, it complicates fining and may reappear in the form of seeds during any subsequent reheating of the glass.

To understand the behavior of carbon dioxide during the melting of glass, scientists have been developing various techniques for quantitative experiments on the successive stages of glass formation.

Reactions Between Carbonates and Silica

During the early study of the fundamental reactions in glass melting, investigators assumed that the reactions between silica and carbonates were of the type: $Na_2CO_3 + SiO_2 = Na_2SiO_3 + CO_2$. P. York, for instance, studied the reactions between silica and alkali carbonates to determine the amount of carbon dioxide replaced when a certain amount of silica is added to a sodium carbonate melt. Later it was found that the amount of carbon dioxide liberated from such a melt was dependent not only upon the ratio of carbonate to silica, but also on the temperature and the time. We know now that an equilibrium is established between the alkali, the carbon dioxide and the silica. Both acids are competing for the base. In an ordinary glass the equilibrium is certainly shifted very far to the side of the silicate, and not much carbon dioxide is left in the melt. However, when the volumes of even small amounts of carbon dioxide are considered, it is of interest to the glass technologist to study even so one-sided an equilibrium.

The amount of gas in chemical equilibrium within a silicate melt free from bubbles can be easily observed by a simple experiment. Heating a mixture of sodium carbonate and silica in the ratio 1 : 1 leads to a melt having the composition of the metasilicate, which is rather fluid and can be easily obtained without large bubbles. When such a melt is cooled very slowly, it starts to crystallize, the precipitation of sodium metasilicate from the melt shifts the equilibrium and carbon dioxide is liberated. Such a basic glass, however, represents an extreme case and we cannot expect an ordinary commercial glass to contain such a huge amount of gas. But commercial glasses do sometimes show formation of gas bubbles in those regions where crystallization has started.

That the carbonates of the alkalies and the alkaline earths begin to react with silica in their solid states has been proved by many authors. The solid phase reaction, however, is at relatively low speed in comparison with the reaction rate observed when a liquid phase is present. The first liquid phase is rich in carbonates and relatively poor in silica, its high fluidity giving rise to increasing reaction between these glass-forming compounds. As silica is dissolved, carbon dioxide is liberated and takes a part in homogeneizing the melt.

When studying a section of a glass which is not entirely melted, we find under the microscope that the sand grains are surrounded by a glass relatively rich in silica. The zone where this glass comes in contact with the bulk of the glass, which is still rather basic, can easily be recognized by the difference in refractive index and by the formation of gas bubbles on the interfacial zone. When all the silica has dissolved the first homogeneizing step has been passed.

Elimination of Carbon Dioxide

At this stage a glass melt resembles sparkling water in many respects. Experiments with a supersaturated solution of carbon dioxide in water may be useful for the general understanding of this important stage of glass melting. Like sparkling water the glass has a tendency to give off the carbon dioxide and to reach an equilibrium, but because of the high viscosity more time is required than is permissible in general plant practice. There are many methods which can be used for reaching the equilibrium more quickly. We know, for instance, that stirring sparkling water favors the liberation of the gas and the same procedure is used in glass practice when optical glass is stirred or glass in the pot furnace is blocked by the use of arsenic or wet organic materials. Another way to decrease the supersaturation is the application of heat. Zschimmer has designed a special heating schedule for melting and fining, his method of using a temperature shock being very valuable for decreasing the gas content. The temperature range, however, is limited by the refractory material and the furnace construction, so there is no possibility of liberating all of the dissolved gas.

Again, if we want to remove carbon dioxide from an aqueous solution at room temperature, a simple means is to apply a slight vacuum. It is difficult, however, to apply this method in glass furnaces, although some special glasses have been melted successfully in a vacuum furnace, in quantities as high as 50 pounds. These glasses, entirely freed from dissolved gases like carbon dioxide and water, have been used in making pump stems for sealing high vacuum tubes, but this procedure is exceptional and will certainly not be applied generally. The present-day method of using fining agents, however, is based on a very similar effect and in the first paper[1] it was pointed out that oxygen bubbles derived from arsenic or antimony have a certain sucking power on the carbon dioxide.

[1] The Glass Industry, July 1938, page 255.

In recent years an entirely new method has been found for liberating gas from super-saturated liquids by ultrasound waves. These waves are mechanical vibrations of a very high frequency which alternately produce pressure and tension in the medium they are traversing. During the tension the material tries to increase its volume and consequently liberates some gas. It seems very reasonable that in the future glass practice will take advantage of ultra-sound wave degassing for special cases.

The degassing, however, can affect only those gases which are physically dissolved and not those in chemical combination. To distinguish between these two types H. Loeffler seeds the silicate melt with sharp crystals of corundum or mullite. Like sharp-edged sand dropped into water, these crystals act as a seeding agent for liberating the gases which are in the supersaturated physical solution.

Methods for Following Reactions

This may be the place to say more about specific methods for following the reactions in the glass batch. The first accurate work was based on chemical-analytical methods with a general trend towards determining the loss of carbon dioxide by weight and finding the reaction of silica with the carbonates by determining the amount of soluble silica formed. The papers of G. W. Cobb published in 1910 may be mentioned as an example. In a similar way P. Niggli studied the reaction of silica with the carbonates of lithium and potassium under a constant carbon dioxide pressure of one atmosphere. Later M. A. Besborodov and collaborators studied the reaction leading to borosilicates by the same methods. For certain details microscopical and X-ray studies proved rather useful. It is possible to find reactions where the transformation of one form of silica to another is involved, or the formation of a sodium calcium carbonate, or similar reactions which cannot be found by analytical methods.

The most accurate work is based on manometric experiments in which the amount of gas liberated from the glass-forming compounds, or from the batch, has been determined in a calibrated apparatus by its pressure. The numerous investigations of W. E. S. Turner and his collaborators dealing with reactions of carbonates and other gas-forming compounds may be mentioned.

As we have said, the solid-phase reactions are very slow in comparison with all reactions where a liquid phase is present. From this point of view it is of interest to distinguish between the carbon dioxide evolved by solid-phase reactions and that appearing in the presence of a liquid phase. Krause and Weyl have used electrical conductivity measurements for determining the first occurrence of a liquid phase. The presence of a liquid does not mean that this phase is necessarily a silicate, for it can be a low-melting eutectic formed from minor batch constituents like fluorides, arsenates, or ammonium salts. For many questions dealing with the reactions in a glass batch, the appearance of the first glassy phase is of fundamental importance. Because of its relatively high viscosity, a glass melt prevents the interaction of the furnace gases. After the point of first glass formation, all further reactions are controlled by the composition of the glass, excluding the furnace atmosphere to a large extent.

Fundamental questions like the dissociation of Fe_2O_3 in glasses, or the reactions of enamels with a metal surface, are definitely influenced by the temperature at which the first glass formation takes place. Since electrical conductivity measurements would not answer this question, a special method has been developed using uranium oxide as an indicator. This method is based on the fact that neither uranium oxide nor sodium uranate show fluorescence if treated with ultraviolet light. When dissolved in glasses, however, even traces of the uranium glass phase can be easily recognized by their strong green fluorescence.

The Determination of Gases in Glass

A great deal of effort has been expended to find the composition of the gases that are dissolved in glass and can be liberated either by heat or by vacuum. Because the amount of gas is relatively small, a large amount of glass has to be used when the generally-known methods of gas analysis are applied. In this way Washburn, Footitt and Bunting studied the gas composition as did Salmang and Becker, who developed a special feeding method for melting the glass.

An entirely different method has been used by Enss who applied a micromethod developed for biological purposes. The gas contained in a seed is liberated by puncturing the glass wall with a sharp point and trapping the glass under glycerine.

By measuring the diameter of the gas bubble under the microscope before and after treatment with different absorbing agents the percentage of each gas can be determined. This method has proved very useful in determining the small amounts of gas contained in seeds and gas bubbles during fining and the absorbents for the different gases are the same as those used in macrochemical gas analysis. In this way the gas content of the glass during the different melting stages may be directly followed.

Another method for the same purpose is based on the spectral analysis of gases. The piece of glass containing the bubble is so heated in a vacuum furnace that the bubble expands under the influence of its own gas pressure. Then the glass is allowed to cool slowly and the bubble, which by this procedure has increased in volume, now contains a gas under a very low pressure. Such a gas can easily be excited in a Teslar high-frequency field and its emission spectrum studied.

The emission spectrum of gases excited in a Geissler tube permits reactions like those between glasses and enamels with metals to be followed when small amounts of gases are liberated. This may be of use for glass-metal seals where a gas formation sometimes takes place due to minor impurities of the metal or to minor constituents of the glass, especially arsenic and antimony.

Exact gas analysis has proved a useful tool for distinguishing between gases which have their origin from the melt itself and air entrapped by the shaping process. A high percentage of nitrogen indicates that entrapped air is responsible for the bubble in the glass.

The determination and analysis of gases do not clearly show the relationship between the gas content of glasses and the composition of the base glass. The analytical experiments prove beyond doubt that the oxygen content depends upon the presence of certain oxides like PbO, BaO, and As_2O_3, but it is not possible to state from present-day analytical knowledge just what chemical com-

pounds are present in a glass. So far as the oxygen is concerned, many oxides of coloring agents can be easily recognized by the absorption spectrum. For instance, the dissociation of Fe_2O_3 to FeO, which takes place upon oxygen evolution, can be easily followed by the absorption in the infra-red. In this way the dependence of the dissociation upon the furnace atmosphere, the melting temperature and time, and upon other factors like the basicity of the glass and the viscosity, can be studied. For investigations of the role of lead or of barium, however, this optical method cannot be applied, because the oxygen content is usually too low for solving this problem by analytical means. For this reason it has proved very useful to shift the gas-glass eqilibrium to higher amounts of oxygen or carbon dioxide by melting the glass under an increased gas pressure. Raising the gas pressure to about 300 atmospheres or, in other words, increasing its concentration 1,500 times higher than in air, could explain some important problems connected with the gas content and with glass colors.

PITTSBURGH PLATE OPENS NEW RESEARCH LABORATORY

At its Columbia Chemical Division plant, Barberton, Ohio, the Pittsburgh Plate Glass Co. has recently completed and occupied a new, well-equipped research laboratory. Colonial in effect, architecturally, the building is constructed of brick with limestone trim and the reinforced concrete floors are carried on steel I-beams. Glass is used extensively throughout the structure, including plate glass for all glazing, Lumite glass block for partitions on the second floor and surrounding the micro-analytical laboratory, glass wool in air filters, tempered glass for special hoods, and safety laminated glass for laboratory shields.

The new building has three floors and a basement, only the second and third floors being above grade on the entrance side. On the second, or entrance, floor are located the offices of the Research Director and his staff, together with the analytical laboratory and another smaller laboratory. The floor above is divided into two large rooms housing the inorganic and physical section, the organic section, and the small room for the micro-analytical laboratory. Part of one of the large laboratories is shown in the accompanying picture. Industrial projects which require handling materials on a larger scale occupy the first floor, together with the main storeroom. Also on the first floor are the technical service laboratory, a physical testing laboratory and a tool room.

The basement is devoted to pilot-plant work, part of it having a ceiling height of 15 ft. to accommodate larger pieces of equipment. A modern heating and ventilating system provides 15 to 20 changes of air per hour throughout the building. Special equipment includes high-pressure autoclaves and bombs designed in the Columbia laboratory, a large centrifuge, and a motor-generator set for electrolytic work. Much of the equipment is mounted on wheels for moving to various parts of the building, all floors of which are connected by an elevator.

In this fine, new laboratory the company will carry out an enlarged program of research and technical service on its well-known chemical products, many of which are extensively used in the plant operations of other American glass manufacturers.

New research laboratory of the Columbia Chemical Division. Pittsburgh Plate Glass Co., Barberton, Ohio. Incorporating three floors and basement, only the second and third floors are above grade on the entrance side.

View in one of the large laboratories on the third floor of the new research building at Barberton. The laboratory is fully equipped with most up-to-date equipment for research work on chemical products.

NOVELTIES IN GLASS LIQUOR MINIATURES

The increasing call for liquor miniatures, though the laws in most all states now prohibit the sale of same, is noteworthy. The idea has become a fad with collectors of these novelties, and some people have made notable collections of these glass containers. While it is true that a large number of liquor miniatures are of the commonplace variety and are sold at very low prices, there are others that not only contain the highest quality liquors from all parts of the world, but the containers themselves are both artistic and costly.

The Palmer House Products liquor store in Chicago has made a feature of miniatures, and today has a stock comprised of about 550 specimens. These include liquors of various kinds from twenty-five countries, representing an almost infinite variety of drinks.

One feature at the Palmer House Products above is that the manager, Charles L. Walker, who is an authority on miniatures, has compiled a large mailing list covering points from coast to coast, where purchases are made by these collectors. Some of the latter have invested large sums in the hobby and makes extensive trips to various parts of the country seeking new ideas and items. In New York there is a large club composed of miniature collectors, where meetings are held and ideas and specimens are exchanged.

A CASE OF OVERSELLING

By ADAM D. BUNKER

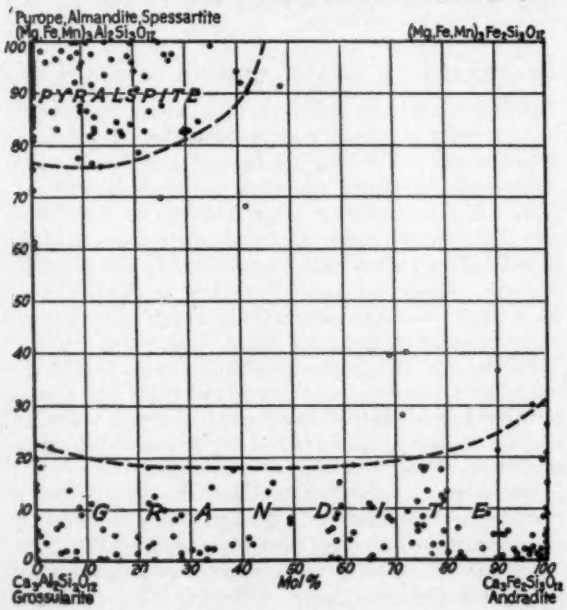
Elmer, the laboratory boy, had had a course in petrography and mineralogy, or perhaps it should have been called microscopy. He learned about the axiality of minerals and to differentiate between uniaxial and biaxial minerals. He could determine if they were positive or negative. At least he did a good job of determining quartz, zircon and calcite as "unknowns" to get his final passing mark.

Along came commencement and Elmer was a lucky boy for he got a job in the lab. There's nothing quite as convincing as enthusiasm and of course youth has that. Elmer didn't want for his share of it either. He had been "sold" on the value of his scientific education, and his training with the microscope was a great embellishment to his proud exit from college into the great industrial world where he would soon do big things. Confidence and self assurance helped Elmer.

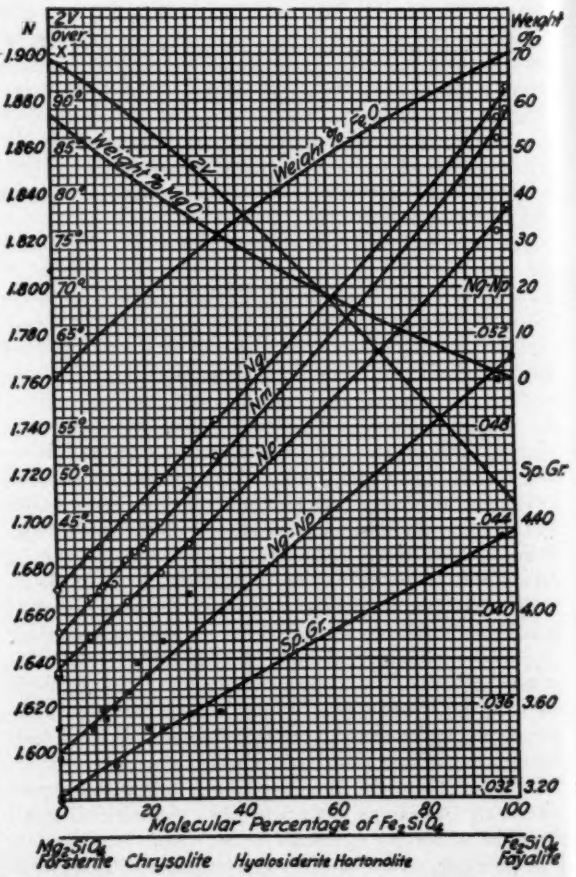
His boss had not had the benefit of a scientific education but he was sure that a Bachelor of Engineering could immediately solve his problems. Confidence and a little selling on Elmer's part got him much of the laboratory equipment they had at school, including a petrographic microscope. That's a fifty cent expression that went over in a big way. It was the most expensive piece of equipment he had asked for so it required a little extra effort to get the boss to O.K. such an order. For help in getting the boss' O.K. he brought forth numerous articles by engineers of the ceramic industry citing what the petrographic microscope will do. Most of these titles were along these lines: "What the Petrographic Microscope Will Do"; "The Petrographic Microscope as a Tool in Industry"; "Plant Control With a Petrographic Microscope." Certainly these articles, with alluring claims by men representing such well known companies, spoke favorably for Elmer's idea.

Time dragged until his panacea for plant ills arrived, but finally it came and Elmer set up to do business: To determine if the refractory failed in the bond or in the crystal phase; to determine if the batch had been properly mixed; to determine what those unusual stones in the glass were and to learn what those minerals were that came to the boss for use in his batch and to decide if the product would be good as indicated by its microstructure. Elmer's greatest nightmare were those unknown minerals he found in his competitor's product and batch.

The reports of petrographic work from Elmer were not too positive—at least that's the way the boss felt and he wasn't sure that the microscope was paying for itself or the time Elmer was spending on it. Some of the minerals Elmer had for identification didn't seem to be like those in the collection at school and neither were they like those listed in the table of natural minerals that Elmer used in his "course." They didn't seem to orient

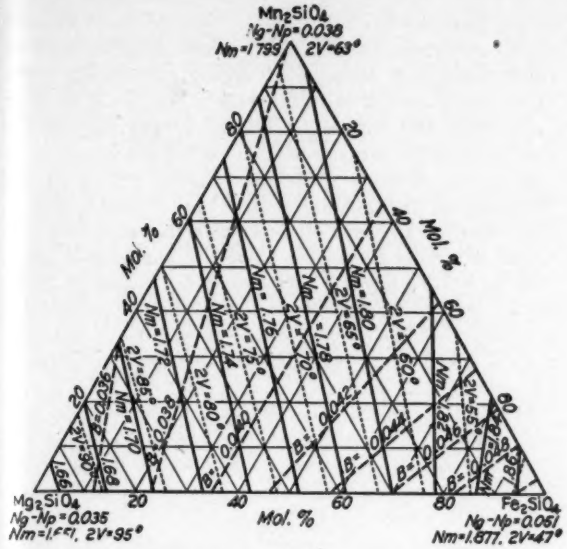


These garnet compositions represent isotropic minerals whose optical properties determinable with the petrographic microscope are meager. Without other supporting information such as specific gravity, dispersion, source, etc., it would be difficult to definitely identify the mineral in a specimen. (Elements of Optical Mineralogy. Winchell.)

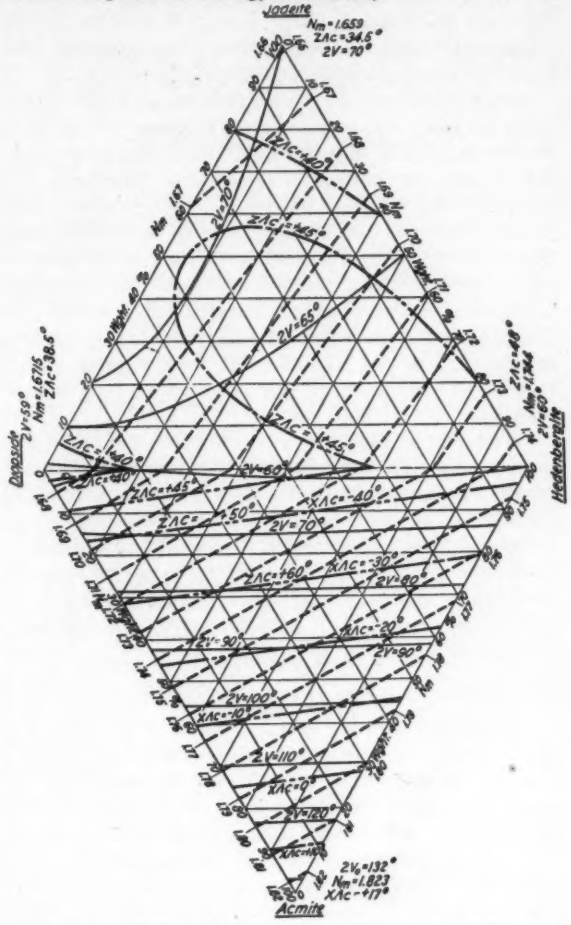


The system Forsterite-Fayalite represents a simple series in which the petrographer can determine the percentage of each constituent by means of the optical properties of the member being examined. (Elements of Optical Mineralogy. Winchell.)

Three component mineral system showing the changes in optical properties with composition. (Microscopic Characters of Artifical Minerals. Winchell.)



Two-three component diagrams of minerals whose optical properties vary with composition making it clear that unless each property is measured accurately the true identity and composition of a mineral might be badly missed. (Elements of Optical Mineralogy. Winchell.)



themselves for interference figures as they were in his collection of thin sections.

There were a few things about petrography and allied sciences that Elmer hadn't learned in school and here are a few of them which made it difficult for him to learn except through the acquisition of considerably more experience than he had had.

These things which Elmer didn't know so much about likewise were omissions from the articles written by our well meaning colleagues who had written so nicely on the subject.

The Index of Refraction of a mineral or other substance gives indication of the rate at which light is transmitted. This property and the numerical value given for the index gives one property by which it can be identified. So it is that glasses which have only one index in contrast with many minerals do not yield positive identification by this means any more so than the color of an animal identifies the species.

Isotropic materials transmit light at the same velocity in all directions. They have only one optical property which can be measured by the microscope, namely, this index. Unless certain crystal characteristics are visible: garnet, for instance, cannot be distinguished from a glass having the same index. The compositions of the two might be radically different. Of course, if the composition is known or if the history of the sample is known, then the microscope may yield valuable information. Too frequently, however, folks, who have been so thrilled with the wonders of the microscope, are disappointed in not being able to obtain more extensive information on isotropic substances whose composition and source they do not know.

Almost the same can be said of crypto-crystalline materials; the individual crystals being so small that optical properties, except index of refraction, cannot be obtained. This leaves considerable doubt as to the true identity of a material.

Very few of the writers of articles referred to previously have given due credit to the assistance that the chemical analysis and other history of a sample gives under conditions such as these. After all, the microscope is only a tool to broaden the view. Too frequently it is looked upon by those who do not know as a means of determining every detail in which we may be interested.

It is possible to determine from the optical character of many minerals to what extent they contain other constituents. Olivene is a popular case. Its index and other properties if accurately determined indicate the percentage of FeO present. It is a member of the series Fe_2SiO_4 — Mg_2SiO_4, the composition varying between these two. The beginner might have difficulty in giving a very complete story on some of the members of the series without other knowledge of its nature, approximate composition, and source.

Fe_2SiO_4 has an extremely high index of refraction. Many of its associates also have high indices and some are even opaque. Opaque minerals cannot be determined by transmitted light and little is divulged in reflected light. Chemical microscopy is frequently resorted to in this case where reactions with known solutions are observed under the microscope.

Series of minerals whose properties vary almost lineally extend into many fields of 3 and 4 components (*Continued on page* 356)

BOOK REVIEWS

• ***The Properties of Glass,*** by George W. Morey, Reinhold Publishing Corporation, New York, 1938 (American Chemical Society, Monograph Series.) THE GLASS INDUSTRY, New York, Sales Agents.

At one step, the English literature on glass in its scientific aspects moves once more to the top of the class. Recent years have seen the publication of a large number of texts in Belgium, France, Italy, Germany, and Russia. Some of these have been trifling, others amateurish, but some have been substantial and sound, and, taken by and large, have been worthy contributions of their several nations. In England and America, there has been a vast outpouring of scientific papers, but the books on glass have been largely confined to artistic aspects, and on the scientific side the texts have either been very elementary or else confined to very limited problems.

Morey's book has been in preparation 14 years, and must necessarily have been largely rewritten several times, for it contains information not published until 1938. It is therefore neither a hurried digest, nor out-of-date. It contains some 500 pages of text and a vast number of graphs and tabular data. In the last respect it naturally invites comparison with the Glastechnische Tabellen; in its title it recalls Bernard Long's work (Proprietes Physiques du Verre); but in its style and plan it follows more closely the monograph of Littleton and Morey on "The Electrical Properties of Glass."

The general attitude of the book may be explained thus: "Here is a lump of glass; describe its properties," and this Morey proceeds to do. He measures all the measurable properties of the glass and reports his findings in text, tables, and figures, and reviews all the relevant literature dealing with those properties, far better, probably, than has been done before in the English language. It will be observed however that this method of treatment, while suitable for the International Critical Tables or the Glastechnische Tabellen, necessarily omits a vast volume of material that vitally concerns the glass manufacturer or glass technologist. It doesn't tell the reader how to make that lump of glass, or another like it. Further, while Morey reports the results of his experiments, he rarely says how he conducted them or what apparatus he used. Thus in spite of the large number of figures, not one is a figure of a piece of apparatus. In spite, therefore, of the similarity of titles, the books of Morey and of Long are very different in character.

Since Morey deliberately excludes the details of manufacturing processes from his consideration, there is here no counterpart of Peddle's "Defects in Glass" or Jebsen Marwedel's more recent work on the subject, nor anything comparable with Wright's "Manufacture of Optical Glass." The exclusion is rigid, and though Morey himself has, more than anyone else, investigated the phase relationships of the Soda Lime Silica Alumina system, there is no discussion of it so far as it relates to the relation between glass and refractory, and the behavior of the hot glass. Neither is there any discussion of the properties of a whole tankful of glass, its mass movement and circulation: the text confines itself rigidly to the final product. *A fortiori,* there is no discussion of raw materials, fuels, forming machines or methods of handworking, or methods of testing commercial ware. Thus Morey's work is in no sense a text book of glass technology, and cannot be likened in any way to the texts of Hodken and Consen, or of Scholes.

Primarily Morey's book is a critical review of the literature on the physical properties of glass, and in this respect it is essentially an extension, though a vast extension, of the Littleton and Morey monograph above referred to. To this has been prefaced a history of glass, far better than most histories of the subject, and a brief discussion of the meaning of the term glass. The first chapter is eminently readable, and indicates the cultural interests of both author and subject.

The second chapter, on Devitrification, is more austere. Since this chapter lends itself to accurate and unequivocal scientific treatment, and since it has been Morey's special field, the chapter is of unusual excellence, but none the less by no means easy reading. It is necessarily a trifle condensed, and would make a book by itself.

Chapter III deals with the composition of the naturally occurring glasses, and of the glasses of commerce. At this stage we begin to run into quantities of tabular data. The "gas" content of glasses is not overlooked, and is better treated than in other works on the subject.

Chapter IV follows somewhat logically with a discussion of the chemical durability of glass, and we now pass from fairly logical science to vast quantities of empirical data. Morey eases the transition by showing why there can be, in our present state of knowledge, no fundamental method of approach, and why empiricism is all that is left to us. But, of course, that does not prevent the whole subject from being boresome in the extreme. Incidentally, the reviewer does not find Figure IV, Page 127, comprehensible with the amount of text allocated to it.

With Viscosity (Chapter IV) we return once more to a less fantastic world, and follow naturally with a discussion of Annealing (Chapter VI). This discussion, of course, is largely on theoretical lines, and the theory has helped practice immensely in some respects, but has kept it barking up the wrong tree for half a generation. This is what comes of a theory that is too perfect.

Chapter VII, on the Surface Tension of glass, begins with a fierce looking thermo-dynamical equation, of which no use can be made. But the text quickly gets down to business.

Chapter VIII deals with the heat capacity of glass (Specific Heat).

This chapter and the next, on Thermal Conductivity, are both short, experimental data being scarce. On the other hand, the tenth chapter, on Density, is very long because data are plentiful. On the face of things density is one of the least important of physical properties and, in the great majority of commercial glasses, it is neither very variable nor is there any ambition to control what variability there is. From a utilitarian point of view, this chapter is too long, and its scientific interest is no greater than its utilitarian.

Chapter XI deals with thermal expansion, which is much more important, and is well treated.

Thermal expansion derives its principal importance, in practice, from its influence on the ability of the glass to stand sudden temperature changes. This is tied up also with tensile strength, and through that with the Elastic Moduli, which form the subject of Chapter XII.

The Strength of Glass is appropriately allocated to Chapter XIII, as being undoubtedly the most unfortunate property that glass possesses.

The clear connection between the three previous chapters and XIV, Thermal Endurance, is well brought out in Morey's first paragraph. In this chapter the mathematics for the first time becomes really serious, Adams and Williamson being quoted at length, and Bessel functions in serried ranks are stretched across the landscape. It is probably as well to have this theory available in the text, although at present thermal endurance, like tensile strength in all its phases, depends much more on obscure surface phenomena than on stresses as calculated from theory or observed photo-elastically.

A short chapter on Hardness (XV) is followed by a long one on Optical Properties, which include transparency, color, refractive index, etc. Figure XVI 9 would be much handier to work with if the CaO content were indicated directly on the base of the diagram.

On Page 423, Morey again becomes highly elliptical. "Brewster showed that under stress the glass behaves as a uniaxial optically negative crystal." This is going altogether too far. What Brewster showed was that under a particular kind of uniaxial stress (probably compressive) the glass behaves as a uniaxial optically negative crystal. But under the opposite sort of stress (uniaxial tension) the glass becomes equivalent to a uniaxial optically positive crystal. And under the more general conditions of stress (three principal stresses of unequal amount) the glass is biaxial, and positive or negative according to the details of the stress system and the composition of the glass.

Chapter XVII and XVIII deal with Electrical Conductivity, and Dielectric Properties. They are long chapters, and follow essentially the thought of Littleton and Morey's "Electrical Properties of Glass," 1933.

Magnetic Properties occupy a brief Chapter XIX and finally Chapter XX discusses constitution. In a sense this has already been partly discussed in the first two chapters.

This book will immediately take its place as the premier text on glass technology in the English language, though it has voluntarily restricted its field. It is not too much to say that, within the field it has marked out, it will be the premier text in *any* language. Unless something unforeseen occurs, it will occupy that position for many years to come.—F. W. Preston.

• ***Glassworking for Luminous Tubes,*** by Henry Eccles, Blandford Press, London. 5 x 7 inches, 143 pages. 36 figures, $2.00.

The art of making letters from glass tubing to form the "Neon" signs which are such a prominent feature of our city streets begins to have a literature. The present work is a technician's book, intended to impart something of the methods acquired in the experience of

(*Continued on page* 356)

Announcing

PROPERTIES of GLASS

By GEORGE W. MOREY

• Dr. Morey's name in connection with any text on glass technology is its own best assurance of outstanding merit. In "The Properties of Glass," however, this eminent authority has achieved his greatest work.

• "The Properties of Glass" is a detailed and critical discussion of all phases of the physical and chemical properties of glass, and how these properties are influenced by their composition. To appreciate the full breadth of the scope of this book, to understand how it differs from other texts dealing with glass, the prospective reader is referred to the accompanying review, page 352. The Table of Contents follows:

General Introduction
Preface
I. The History and Definition of Glass
II. The Devitrification of Glass
III. The Composition of Glass
IV. The Chemical Durability of Glass
V. The Viscosity of Glass
VI. The Annealing of Glass
VII. The Surface Tension of Glass
VIII. The Heat Capacity of Glass
IX. The Heat Conductivity of Glass
X. The Density of Glass
XI. The Coefficient of Expansion of Glass
XII. The Elastic Properties of Glass
XIII. The Strength of Glass
XIV. The Thermal Endurance of Glass
XV. The Hardness of Glass
XVI. The Optical Properties of Glass
XVII. The Electrical Conductivity of Glass
XVIII. The Dieeetric Constant, Dielectric Loss, and Dielectric Strength of Glass
XIX. The Magnetic Properties of Glass
XX. The Constitution of Glass
Indexes

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CURRENT PRICES OF GLASS-MAKING MATERIALS

FURNISHED BY PRODUCERS, MANUFACTURERS AND DEALERS

Base Materials

		Carlots	Less Carlots
Barium carbonate ($BaCO_3$), Crude, (Witherite) 90%, 99% through 200 mesh	ton	43.00	46.00
Barium sulphate, in bags	ton	19.00	24.00
Barium sulphate, glassmaker's, carlots, bulk f. o. b. shipping point	ton	15.00-16.00	18.00
Borax ($Na_2B_4O_7 10H_2O$)	lb.	....	....
Granulated	In bags, lb.	.0215	.027 -.0295
Powdered	In bags, lb.	.024	.0295-.032
Boric acid (H_3BO_3) granulated	In bags, lb.	.048	.054 - .0565
Calcium phosphate ($Ca_3(PO_4)_2$)	lb.	.07	.07½
Cryolite ($Na_3Al\ F_6$) Natural Greenland (Kryolith)	lb.	.0875	.0925
Synthetic (Artificial)	lb.	.0825	.0875
Feldspar—			
20 mesh	ton	11.00-13.25	
40 mesh	ton	11.50-13.75	
Granular	ton	11.75-14.00	
Semi-granular	ton	11.00-13.25	
L. C. L., (Min. 2 tons) $3.00 per ton additional plus charge for bags			
Fluorspar (CaF_2) domestic, ground, 96-98% (max SiO_2, 2½%)			
Bulk, carloads, f. o. b. mines	ton	30.00	....
In bags	ton	31.60	38.00-40.60
Kryolith (see Cryolite)			
Lead Oxide (Pb_3O_4) (red lead) (N. Y.)	lb.	.074	....
In 5 Ton lots	lb.	....	.0775
Less than 5 Tons	lb.	....	.0825
Lime—			
Hydrated ($Ca(OH)_2$) (in paper sacks)	ton	10.50	....
Burnt (CaO) ground, in bulk	ton	7.00	....
Burnt, ground, in paper sacks	ton	9.00	....
Burnt, ground, in 280 lb. bbls.	Per bbl.	2.25	2.25
Kiln Dried ($CaCO_3$) 10x30 mesh	ton	1.75	....
Kiln Dried ($CaCO_3$) 16x120 mesh	ton	1.75	....
Potassium carbonate—			
Calcined (K_2CO_3) 96-98%	lb.	.065	.0675
Hydrated 80-85%	lb.	.055	.0575
Salt cake, glassmakers (Na_2SO_4)	ton	15.00	25.00
Soda ash (Na_2CO_3) dense, 58%—			
Bulk	Flat Per 100 lb.	.95	....
In barrels	Per 100 lb.	1.35	....
In bags	Per 100 lb.	1.10	....
Sodium nitrate ($NaNO_3$)—			
Refined (gran.) in bbls.	Per 100 lb.	....	2.50-2.90
95% and 97%			
Bulk	Per 100 lb.	1.35	....
200 lb. bags		1.415	1.44
100 lb. bags		1.45	1.475

Special Materials

		Carlots	Less Carlots
Aluminum hydrate ($Al(OH)_3$)	lb.	....	.03½
Aluminum oxide (Al_2O_3)	lb.	.04	.05
Antimony oxide (Sb_2O_3)	lb.	.11½	.12¼
Arsenic trioxide (As_2O_3) (dense white) 99%	lb.	.03	.03½
Barium nitrate ($Ba(NO_3)_2$)	lb.	....	.07¾
Nepheline syenite—			
Pyrophyllite, (20% Al_2O_3)	ton	9.00	12.00
Rutile (TiO_2) powdered, 95%	lb.	.08½-.09½	.10-.11
Sodium fluosilicate (Na_2SiF_6)	lb.	.04¼	.05
Tin Oxide (SnO_2) in bbls.	lb.	....	.48
Zinc Oxide (ZnO)			
American process, Bags	lb.	.06¼	.06½
White Seal, 150 lb. bbls.	lb.	.08¾	.09
Green Seal bags	lb.	.08	.08¼
Domestic White Seal bags	lb.	.08½	.08¾
Red Seal, bags	lb.	.07½	.07¾
Zircon			
Refined Granular (Milled .01-.02c higher)		.06½	.07-.08
Commercial, Gran. (Milled .02¼-.02½ higher)		.02¾	.03-.03½

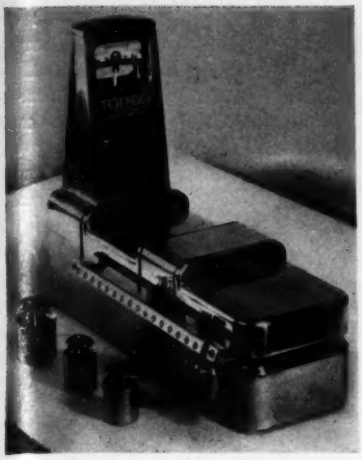
Coloring Materials

		Carlots	Less Carlots
Barium selenite ($BaSeO_3$)	lb.	....	1.40-1.60
(Commercial, 25% Selenium)	lb.	....	.90
Cadmium sulphide (CdS)	lb.	....	1.05-1.20
Chromite (99% through 200 mesh)	lb.	37.00	40.00
Cerium hydrate—			
100 lb. drums and 600 lb. barrels	lb.	....	.60
Chrome Oxide Green, 400 lb. bbls.	lb.	....	.22-.26
Cobalt oxide (Co_2O_3)			
In bbls. 350 lbs. or more,	lb.	....	1.67
Less than 350 lbs.,	lb.	....	1.77
Copper oxide—			
Red (Cu_2O)	lb.	....	.185
Black (CuO)	lb.	....	.145-.15
Black prepared	lb.	....	.22
Iron Oxide—			
Red (Fe_2O_3)	lb.	....	.0425
Black (Fe_3O_4)	lb.	.04½	.09
Iron Chromate	lb.	....	.035-.05
Lead Chromate ($PbCrO_4$)	lb.	....	.16
Manganese, Black Oxide			
In Paper bags	ton	57.50	60.50-65.50
In Burlap bags	ton	59.50	62.50-67.50
In Casks	ton	61.50	64.50-69.50
Neodymium oxalate, 50 lb. drums	lb.	....	3.50
Nickel oxide (Ni_2O_3), black	lb.	....	.35-.40
Nickel monoxide (NiO), green	lb.	....	.35-.40
Potassium bichromate ($K_2Cr_2O_7$)—			
Crystals	lb.	.08¾	.09-.09¼
Powdered	lb.	....	.09¼-.09¾
Potassium Chromate (K_2CrO_4) 100 lb. kegs	lb.	....	.27
Powder blue	lb.	....	.2075-.2125
Rare earth hydrate—			
100 lb. drums	lb.	....	.35
325 lb. barrels	lb.	....	.30
Selenium (Se) In 100 lb. lots	lb.	....	1.75
In lesser quantities	lb.	....	1.85
Sodium bichromate ($Na_2Cr_2O_7$)	lb.	.06¾	.07-.07¼
Sodium chromate (Na_2CrO_4) Anhydrous	lb.	.08¼	.08¾-.08⅝
Sodium selenite (Na_2SeO_3)	lb.	....	1.65-1.75
Sodium uranate (Na_2UO_4) Orange	lb.	....	1.50-1.55
Yellow	lb.	....	1.50-1.55
Sulphur (S)—			
Flowers, in bbls.	Per 100 lb.	3.35	3.70-4.10
Flowers, in bags	Per 100 lb.	3.00	3.35-3.75
Flour, heavy, in 250 lb. bbls.	Per 100 lb.	2.90	3.25-3.65
Uranium oxide (UO_2) (black, 96% U_3O_8) 100 lb. lots. Black	lb.	....	2.25-2.30
Yellow orange	lb.	....	1.50-1.55

Polishing Materials

		Carlots	Less Carlots
Emery, Turkish	lb.	.063	.07
Pumice Stone,			
American Ground Italian FFF, FF, F	lb.	....	.03
0, 0½, ½, 1	lb.	....	.03¼
Putty Powder	lb.	....	.38-.42
Rotten Stone, (Domestic)	lb.	....	.02
Rouge, Red	lb.	....	.14
Black	lb.	....	.16

EQUIPMENT AND SUPPLIES



"SPEEDWEIGH" SCALE

For weighing materials, packages, pieces, etc., to a predetermined weight, the Toledo Scale Co., Toledo, Ohio, has just brought out a new scale of the "over-and-under" type, designated Speedweigh. The new scale is furnished in two models, one with the indicator tower at the end and one with the tower in the center, the former being shown in the accompanying illustration. Each model has a capacity of 5 pounds and will indicate to 1/64 ounce, the standard indicator travel being one inch per ounce.

The Speedweigh scale incorporates two platters, on one of which necessary weights may be placed while the article to be weighed is placed on the other. One two-pound and two one-pound weights are supplied, these being button-handled, chrome-plated, steel weights of high accuracy. For setting the predetermined weight to a fraction of an ounce a notched beam with a movable, chrome-plated poise is located at the side of the scale, the beam being made of stainless steel with etched figures and graduations.

The housings and platters of the new scale are made of polished, die-cast aluminum, the construction being such as to protect the scale mechanism against the entrance of dust and provide accurate location of bearings in the base. As shown in the illustration, the platters overhang the base, thus promoting stability through wide-spaced load pivots, as well as diminishing the entrance of dust. The casting at the top of the indicator tower can be pulled up a short distance to provide a carrying handle, and the light weight of the scale makes it readily portable. The shipping weight of each model is approximately 25 pounds.

The manufacturer states that the internal construction is such as to insure accuracy over a long period. Tool-steel pivots and bearings and replaceable self-aligning bearings are used. A self-adjusting, hydraulic shock absorber controls the indicator oscillations and adjustable stops beneath the scale platters go into action at each extreme of the indicator pointer travel. Corrosion-resisting treatments have been applied to the interior working parts as a protection against the action of moisture, acid, fumes, etc. Additional sturdiness is secured by mounting the indicator chart directly on the base casting of the machine so that it is not affected by any strain put on the tower housing.

The base of the model shown has a width of 6 in. and a length of 17⅝ in., three supports being provided for stability, but the scale does not have to be carefully leveled for accurate weighing. Height from bottom to commodity platter is 5¼ in. and from the platter to the reading line of the chart is 7¾ in. Overall height is 15 in. Commodity equipment available includes a round pan and a confectionery scoop, in addition to the weight and commodity platters.

BULLETINS RECEIVED

Laclede-Christy Clay Products Co., St. Louis, Mo. A new 12-page illustrated bulletin describes the makeup and use of Furnaseal Plastic Fire Brick and Super Plastic. Items of special interest include information on monolithic furnace linings, anchorage data and engineering specifications.

Elwell-Parker Electric Co., Cleveland. New technical bulletin describes and illustrates the Type E-1 tiering, telescoping platform truck, with rated capacities of 3,000 and 4,000 pounds.

South Bend Lathe Works, South Bend, Ind. Catalog No. 46-A gives complete data on a new 12-speed, 9-in. swing lathe, together with many hints on best machine shop practice.

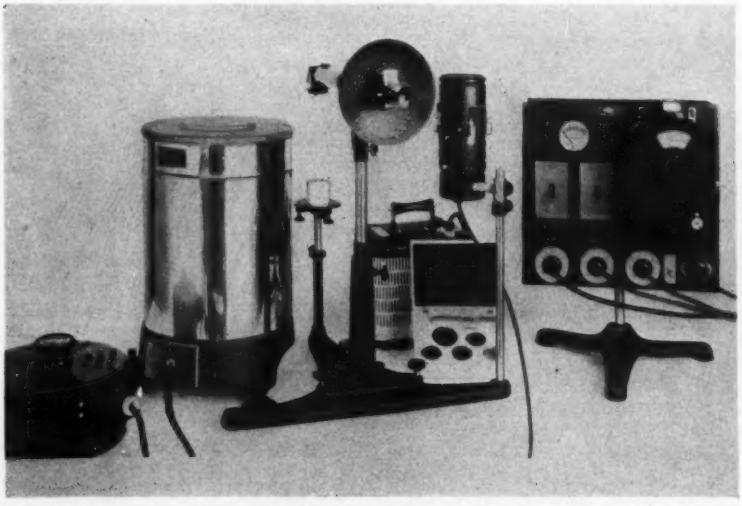
Stearns Magnetic Mfg. Co., Milwaukee. New 8-page folder describes the construction and operation of Stearns' magnetic separators of the spout type for removing tramp iron.

GAERTNER IMPROVED INTERFEROMETER

The Gaertner Scientific Corp., Chicago, is marketing improved models of its interferometers for thermal expansion measurements. These instruments are especially adapted for the determination of thermal expansion at temperatures as high as 1,000°C., as well as for flexures or other small motions or changes in length.

In the improved models the viewing apparatus is mounted on a cast-iron base which also holds a small table for the adjustment of the interferometer and a mercury-arc lamp with filters. The light is reflected by a stationary prism along the vertical axis of the viewing apparatus. The latter may thus be rotated between different furnaces and the test table without discontinuity of illumination and without the necessity of moving the lamp with the apparatus as formerly.

The viewing apparatus also has new counting aids for the fringes, together with a device for quickly checking the leveling and parallelism of the plates. The interferometer plates are made of best quality of fused quartz, according to the manufacturer. The electric furnace for the thermal-expansion interferometer now has an attractive cast-iron base and stainless-steel shell, with an embedded Kanthal heating element and solid insulation. A convenient portable indicating and control panel is furnished. Bulletin No. 140 illustrates and describes the improved instruments in detail.



BOOK REVIEW

(*Continued from page* 353)

the writer. It is quite probable that no one, without other training or instruction, could master the lampworking art from the book, any more than he could learn to swim by similar means. The skilled lampworker might acquire additional skill, and profit by the careful description of the highly specialized processes of sign-making. The general reader may satisfy his curiosity concerning this little-known art.

The smattering of information about tube glasses in the opening chapter is not particularly good. The author describes soft soda glass as though it had the empirical formula, $Na_2O.CaO.6SiO_2$, which is more nearly descriptive of plate glass, while at the same time he assigns a softening temperature below 500° C to this glass. He states very broadly that pyrex softens at "6-800° C." These estimates are obviously low.

A good deal of reliance is placed upon the method of annealing in the flame, which is traditional with lampworkers. The remark is made that some manufacturers have found that this is fully as efficacious as oven annealing. Most workers with glass have found that the flame method is entirely too casual, as compared with lehr or kiln treatment. In the description of the strain finder, the author makes the interesting statement that the magenta background results from reflection from a plate of manganese glass. A tint plate in the tube carrying the Nicol is the more usual method of getting this effect.

The lampworker's blast lamp or torch is described as a "blow-pipe," a term seldom used in this country. Also the author refers to the glass as "mettle," whereas the usual spelling is "metal."

However, when Mr. Eccles is writing about the operations themselves, he is on sure ground; and he describes the various seals and bends and the manner in which they are produced, including details of handling the tubes, temperature of heating, and the application of tools, with the ease and familiarity that comes only from long experience. Suggestions for planning the work, for carrying through the entire project in regular order, and for maintaining a neat workbench are made in a sympathetic, informal style; and this part of the book should offer encouragement and help to any beginner, if not to a skilled lampworker.

Since this means of producing light by the fluorescence of vapors carrying a silent electric discharge may eventually find utility for more general illuminating purposes, as well as for colored signs, this book is very welcome as one of the first attempts to portray the technique necessary for its accomplishment.—S.R.S.

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Write for complete information.

Industrial Division
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Dunellen, New Jersey

Mixer Specialists since 1850

Ransome MIXERS

A CASE OF OVERSELLING

(*Continued from page* 351)

as indicated in the accompanying figures. These are not simple systems and while it would appear that because all of these data are available and therefore make identification of any member possible, this is not readily done either by a beginner, or even a more experienced petrographer without considerable other contributing information.

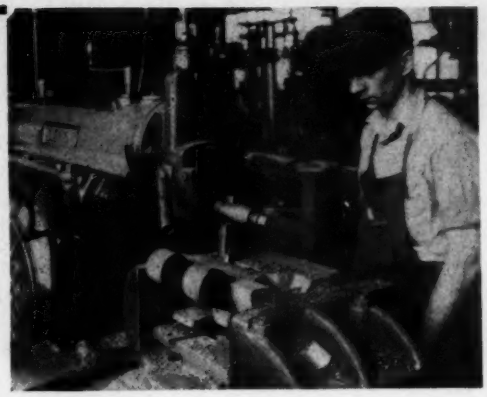
A thorough knowledge of crystallography, a breadth of experience in petrographic determination including "tricks of the trade" not learned from books, a knowledge of mineral chemistry and reactions between minerals at high temperatures all make it possible for Elmer to see more and more and write better reports. He will learn the effects of solid solution upon the optical properties of minerals. He will learn what minerals to expect coexisting in a processed product and he will find that chemical analysis, information as to sources of the specimen, the previous heat treatment, if any, and the chemistry involved, all form as important a part in identification as the manipulation of the microscope.

J. EDWARD MURRAY IS DEAD

It is with regret that THE GLASS INDUSTRY records the death on August 14th, 1938, of J. Edward Murray, president of the Maryland Glass Corporation, Baltimore, Maryland.

MIDGET SUN ANNOUNCED

A midget sun in the form of a 1,000-watt mercury lamp, no larger than a cigarette, yet designed to attain a brilliancy equivalent to about one-fifth that of the sun's surface, has been announced by the Incandescent Lamp Department of the General Electric Co. The new lamp consists of a small quartz tube. Confined within the tiny bore inside the tube is a globule of mercury and a trace of argon gas. Each of the quartz tubes is furnished with a brass ferrule to provide electrical contact.



Machining the face of a section for a bottle mould.

• The production of moulds for glass manufacturing is a task in which high grade workmanship is combined with first-class equipment.

THE TOLEDO MOULD COMPANY
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BINNEY

MIN-OX
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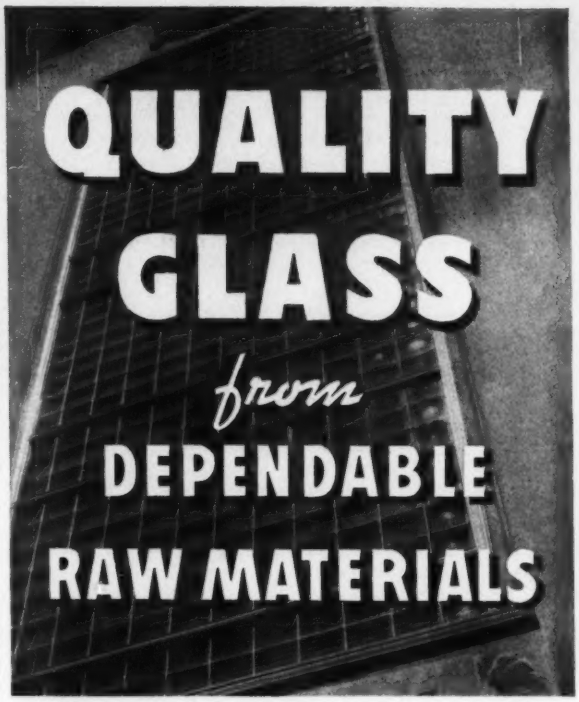
"For Sheer Brilliance"

MIN-OX moulds, because they are made of scientifically developed alloys, give greater brilliancy to glassware and greater fidelity to design in intricate mould work. This means increased sales.

In addition to increasing your sales, MIN-OX moulds cut production costs—by practically eliminating fire-finishing—by reducing cleaning costs—by giving longer life.

Lowered costs plus increased sales equal greater profits—that's what MIN-OX will do for you.

THE BINNEY CASTINGS COMPANY
TOLEDO, OHIO
originators of alloys for glass molds



The silent efficiency of modern glass is usually taken for granted. But modern glass for bottles, building bricks, better lenses, windshields, glass cloth . . . requires methods of processing that were unknown a century ago.

In this age of specialty, technicians must be able to *depend* on the quality, the specified grade, the purity of raw materials they use in making glass. Solvay products are dependable and uniform. They have withstood the challenges of the advancements in the art of glass making for over a half century . . . *they match the requirements of today's high standards!*

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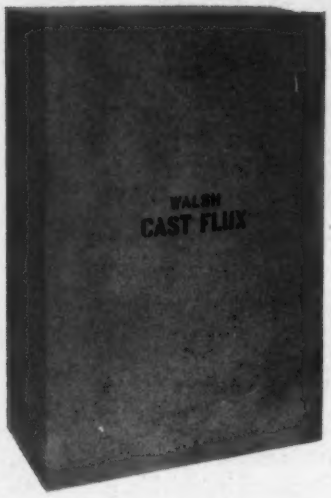
SOLVAY
58% DUSTLESS DENSE
Soda Ash

WALSH CAST-FLUX



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Walsh Cast-Flux blocks are machine-trued to exact size and shape after burning.

THEY LAST LONGER

The excellent results obtained in numerous tanks melting various types of glass has definitely established the efficiency and economy of Walsh Cast-Flux blocks.

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LANCASTER OHIO

GORTONS MAKE THE MOULDS FOR MARYLAND BOTTLES

Blue glass bottles are familiar sights in drug stores where they are sold in quantities with contents that are good for what ails you. A large part of the product of Maryland Glass Corp. consists of blue glass bottles of the characteristic rich, deep color. The molds for many of them are made on Gorton Duplicators. For the reason, let's take a look in the time book of the Mould Shop foreman on a typical case like this 32 oz. Milk of Magnesia bottle.

The moulds for this bottle were produced on the Gorton Duplicator in half the time formerly required.

	Produced on a Gorton Duplicator			By Previous Methods	Time Saved
	Duplicator Time	Hand Work	Total		
Bottle Moulds, 9 halves	28 hrs.	87 hrs.	115 hrs.	182 hrs.	67 hrs.
Bottom Plates, 4	4	12	16	27	11
Blanks, 9 halves	14	21	35	122	87
Total Time	46 hrs.	120 hrs.	166 hrs.	331 hrs.	165 hrs.

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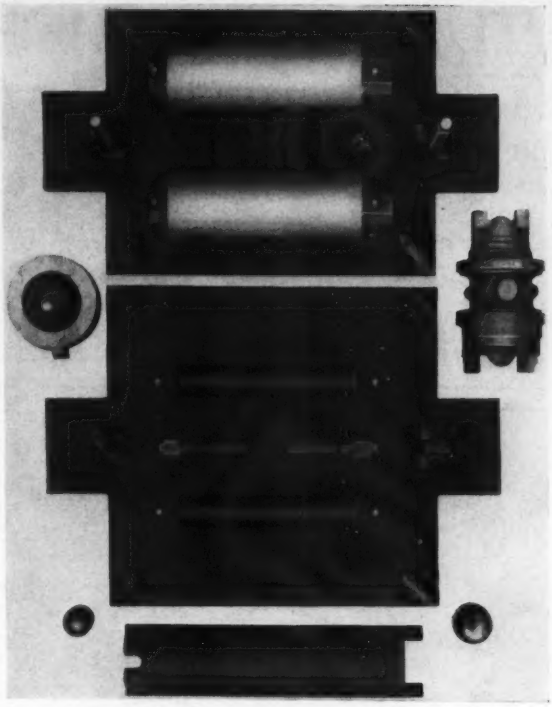

Speedy Delivery with Metal Patterns for Gunite Glasshouse Castings

Because an ample supply of metal patterns are always kept in stock, your orders can be speedily filled by GUNITE. But, in addition to quick delivery, there are the superior qualities of GUNITE to be considered.

GUNITE has just the right hardness and polish to produce lustrous, smooth ware unusually free from defects. Lowered costs of replacements, absence of spoiled ware and fewer shutdowns—make GUNITE the most economical metal for moulds and mould parts.

GUNITE's knowledge of the problems of the glass industry is based on 15 years of research and five years of testing under actual operating conditions. Send for the booklet describing the complete line of GUNITE castings—round bar stock, Miller plungers, and guide rings, neck ring sticks, bushing stock, press and blow moulds, and metal patterns.

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